Monterey-Salinas Transit ITS Augmentation Project
Final Phase II Report

Submitted to:
United States Department of Transportation

Submitted by:
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and
TranSystems

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1 Cabot Road
Medford, MA 02125</td><td colspan="2">10. Work Unit No. (TRAIS)</td></tr>
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The goal of the evaluation was to determine the impacts of these technologies in performing daily functions such as operations, scheduling, service planning, and maintenance, and to gather and document any lessons learned by the MST throughout the process of the deployment and operation of the technologies. This report discusses impacts to date of the technologies that have been in place for at least one year as of August 2008. Findings from customer satisfaction interviews and impacts of real-time information, transit signal priority and web-based trip planning on MST operations will be documented in the Phase III report.
Even though the Evaluation Team was not able to derive conclusions on the direct impact of technology for certain expected changes (e.g., increased ridership, improved on-time performance), anecdotal information obtained from MST staff has provided significant evidence to show that, so far, technology has made significant improvements in operations and planning. Generally, technologies have played a significant role in improving the efficiency of all departments as reported by the MST management. Improved efficiency has helped MST achieve cost savings as well. It is expected that even more benefits will be realized as these technologies are relied upon even more to perform specific operational and management functions.</td></tr>
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GLOSSARY OF ACRONYMS

AADT	Annual Average Daily Traffic
AAS	Automated Annunciation System
ACS	Advanced Communication System
ADUS	Archived Data User Services
APC	Automatic Passenger Counters
AVL	Automatic Vehicle Location
AVA	Automatic Vehicle Annunciation
BRT	Bus Rapid Transit
CAD	Computer Aided Dispatch
COA	Comprehensive Operational Analysis
DDAM	Daily Dispatch and Attendance Management
FAMIS	Financial and Accounting Management System
ITS	Intelligent Transportation System
JPO	Joint Program Office
MMS	Maintenance Management System
MOE	Measures of Effectiveness
MST	Monterey-Salinas Transit
NTD	National Transit Database
RTIS	Real-Time Information System
TSP	Transit Signal Priority
USDOT	United States Department of Transportation

EXECUTIVE SUMMARY

The purpose of this document is to present the findings from the Phase II Evaluation of the Intelligent Transportation Systems (ITS) Augmentation Project that was implemented at the Monterey-Salinas Transit (MST) in Monterey, California. This project, implemented using the Federal Fiscal Year 2003 ITS Integration Program Funds, originally included automated passenger counting (APC) technology, digital video surveillance, on-board automated vehicle annunciation (AVA), smart-card based fare payment, web-based trip planning, and real-time information systems. Although many of these systems were already implemented as of August 2008, deployment of some of these technologies has been delayed for institutional or technical reasons.

Background on Monterey Salinas Transit

Monterey-Salinas Transit (MST) is one of the three major transit providers in Monterey Bay area. MST was formed in 1981 after the merger of the Salinas Transit System with the Monterey Peninsular Transit. Currently, MST serves an approximately 280 square-mile area of Monterey County and Southern Santa Cruz County. MST provides service to the 352,000 residents of Monterey County. MST also provides curb-to-curb paratransit transportation services, RIDES, to the residents of MST service area who need specialized transportation. RIDES is operated by MV Transportation.

MST serves the Monterey Peninsula and Salinas Valley areas with 36 fixed routes. MST provides service between these two urban areas of Monterey County via Highway 68 and Highway 1.

In addition to the Monterey-Salinas area, intercity routes connect MST with the Santa Cruz Metropolitan Transit District. MST also provides rural transit service to Carmel Valley and seasonal service to Big Sur. Recently, MST has added express commuter routes to its service on two corridors: Monterey and San Jose, and Salinas and King City.

In addition to regular and express routes, MST operates trolleys that serve the area along the Monterey and Pacific Grove waterfronts.

Background on the ITS Augmentation Project

MST received Federal earmark funding in 2003 to procure and implement technologies to meet their daily organizational needs. These technologies were implemented under a project named the ITS Augmentation Project. The ITS Augmentation Project was primarily intended to assist MST in improving customer information and convenience, on-time performance, operational efficiency and management, and safety and security. Additionally, the project was expected to enhance reporting and implement automated passenger counting.

MST's goals for the ITS implementation as they relate to Federal Transit Administration (FTA)/USDOT goals were identified as follows:

FTA/USDOT Goals	MST Issues Addressed by ITS Technologies
Increased Productivity	Route performance and cost
	Maintenance scheduling and management

FTA/USDOT Goals	MST Issues Addressed by ITS Technologies
Improved Mobility	Customer information and convenience
Improved Efficiency	On-time performance
	Operational efficiency and management
	Enhanced reporting
	Automated passenger counting
Improved Safety	Safety and Security

The following technologies were selected by MST for implementation as part of the ITS Augmentation Project:

- On-board technology for automatic passenger counting (APC);
- Automatic vehicle Announcements (AVA);
- Upgraded transit management and planning software;
- Digital cameras on buses and in transit centers;
- Making security images available to local public safety agencies;
- Archived Data User Service (ADUS);
- Real-time information system (RTIS);
- Transit Signal Priority (TSP);
- Translink program (San Francisco Bay Area smartcard fare payment system); and
- Improved MST website to provide trip planning and bus location information.

Some of the above technologies (e.g., passenger counting and AVA) were integrated with the existing Advanced Communication System (ACS) system, which was procured under a separate grant in 2002. The ACS is a global positioning system (GPS)-based computer aided dispatch and automatic vehicle location (CAD/AVL) system.

Most of the technologies identified in the ITS Augmentation project have been implemented as of August 2008 with the exception of a few. MST has decided not to use the Translink program due to current institutional issues among participating agencies and the vendor. The web-based trip planner is not deployed as of August 2008 but MST expects to deploy Google Transit trip planner by Fall 2008. MST decided not to participate in TakeTransit trip planner offered by the Metropolitan Transportation Commission (MTC) in San Francisco Bay Area even though that was identified in the original scope of this project. MST has not yet implemented TSP because all of the project stakeholders have yet to reach consensus regarding the benefits of this technology. The dynamic message signs (DMS) providing real-time information have been installed at two locations. Please refer to Section 1.2 of this report for further details on the deployment status of each technology.

MST has procured other technologies since the implementation of the ITS Augmentation Project to reduce manual process and improve efficiency. For example, they implemented a financial accounting and management software (FAMIS[1]) in 2006, a new payroll system in 2008 and maintenance management system (MMS) in 2006. MST has also installed on-board internet access on vehicles serving the two commuter routes.

Background on the MST ITS Evaluation

The USDOT ITS Joint Program Office (JPO) established a National ITS Evaluation Program to determine the impacts of ITS deployments across the country. The objective of these evaluations is to document findings that can be used by a wide variety of external audiences such as planners, engineers, and managers. The results of these evaluations assist in the planning and implementing of future ITS projects with help of lessons learned from systems already implemented.

The USDOT/JPO selected the MST ITS Augmentation Project for an evaluation to be conducted by an independent Evaluation Team comprised of SAIC and TranSystems (referred to as the Evaluation team in this report). The two-fold purpose of this evaluation is to evaluate the use of archived ITS data for improving service planning and operations, and to evaluate the costs and benefits of implementing the MST ITS Augmentation Project. The ACS was evaluated along with the technologies that are part of the Augmentation Project since these technologies were integrated with the ACS. Further, the ACS was evaluated since it contributes significantly to achieve the ITS Augmentation Project goals (e.g., on-time performance). Also, the Evaluation Team analyzed the impact of other technologies that were not procured with the Federal earmark funding (e.g., FAMIS and MMS) but have made significant contributions to improvements at MST.

The evaluation is being conducted in three phases. Phase I of the evaluation was an initial assessment of the implementation of the Augmentation Project by the Evaluation Team. This Phase was completed in October 2005 when the Evaluation Team submitted their Phase 1 findings to the USDOT JPO. These findings assisted the USDOT/JPO in deciding to proceed with a full evaluation of MST's Augmentation Project. Phase I results are not included in this Evaluation Report.

Phase II (this phase) focused on a "before" and "after" analysis of the technologies that have been fully deployed. Additionally, Phase II includes a "before" analysis of the technologies that are planned to be deployed in the future.

Phase III will consist of an "after" analysis of those technologies that are currently planned for deployment. The evaluation approach adopted for Phases II and III is discussed in Section 2 of this report.

Conclusions of the Evaluation

This report describes the findings from Phase II of the evaluation. The evaluation was conducted by testing the hypotheses identified in the Evaluation Plan submitted to USDOT in January 2007. Data collection and analysis were conducted according to the Test Plan submitted to USDOT in June 2007. The evaluation was based on six key hypotheses and nine secondary hypotheses. These hypotheses were tested by analyzing quantitative data obtained from MST, and qualitative data obtained by interviewing MST staff. The

[1] FAMIS is a term used by MST to refer to their financial and accounting system. This is not an official product name for the system.

Evaluation Team would like to thank MST staff as they have made significant contributions to this evaluation by providing data and anecdotal information.

The evaluation of ITS deployment at MST has resulted in the identification of key factors about MST's experience related to the procurement, implementation, management and utilization of ITS technologies. Also, the evaluation identified the impacts of the technology on various departments at MST.

The following paragraphs provide a summary of the preliminary evaluation findings with respect to both key and secondary hypotheses. The results of testing the hypotheses revealed that they were either supported or inconclusive. For example, a few of these hypotheses (e.g., related to the improvement of on-time performance, and increase in ridership) were not supported by the data. The contribution of related technologies was not obvious due to involvement of external factors (e.g., service change, and operational improvements). Further, given that it takes considerable time for technologies, such as those deployed at MST, to stabilize, to become integral to agency operations and management, and to be accepted by staff, each hypothesis will be re-examined in Phase III of the evaluation to provide more definitive conclusions.

The key hypotheses for this evaluation are:

- <u>Hypothesis: The project will result in a reduction in operations and planning costs and improved service planning.</u> The Evaluation Team found increases in annual revenue and annual revenue per passenger-mile from the time of the technology implementation. However, it is not obvious that the improvements have been due to technology. Also, quantitative estimates of benefits perceived by MST departments were not available for most technologies. MST has provided some basic estimates of savings from technologies such as from the deployment of scheduling software called HASTUS, and fuel management systems as highlighted in Section 3.7.5.

  MST provided anecdotal evidence of benefits perceived from ITS implementations (as of August 2008) which provide the basis for the fact that technology contributed to service planning and operations improvements. MST reported improvements in service planning due to the accuracy and reliability of the archived ACS data used in recent comprehensive operational analysis (COA) studies. Also, MST has been able to reduce the cost of data collection by reducing the manual effort required by COA studies (e.g., recruitment of temporary staff). Among other benefits, MST utilizes archived data from the ACS for analysis with the help of other tools such as ArcView, Microsoft Excel and Access for planning needs (e.g., using passenger count data for determining stop and shelter needs and appropriate locations).

- <u>Hypothesis: The project will result in improved on-time performance of MST operation.</u> The preliminary results showed that this hypothesis cannot be supported with the currently available data (as discussed in the analysis of on-time performance in Section 3.1.2.2). The results were inconclusive because MST had several changes in planning and operations during the time period selected for analysis. Therefore, this hypothesis will be re-examined in Phase III of the evaluation.

  The intent of this hypothesis was to determine if there were improvements in schedule adherence due to the availability of real-time vehicle information for dispatchers and supervisors. Also, the Team wanted to evaluate the impact of MST's ability to adjust schedules by utilizing the archived ACS data. However, it is not clear from the changes in on-time performance on selected routes whether those changes were due to the impact of technology or due to the operational changes.

MST staff believes (see their detailed input in Section 3.1.2.2.2) that on-time performance has improved since the technology implementation and technology has contributed directly or indirectly to this improvement (e.g., by providing data for COA analysis and subsequent service restructuring).

- <u>Hypothesis: The project will result in an increase in the reliability of services.</u> This hypothesis is similar to the previous hypothesis related to on-time performance and was not supported as a result of the evaluation.

  Since the quantitative assessment of ACS data is inconclusive; the reliability of MST service should be measured by performing a qualitative assessment of customers' perception of on-time performance. It is recommended that this hypothesis be revisited during Phase III of evaluation while conducting surveys to measure customer satisfaction.

- <u>Hypothesis: The project will enhance system productivity.</u> This hypothesis is supported by several statistics that serve as indicators of productivity improvements (e.g., revenue per passenger-miles and passenger-miles). However, these statistics are inconclusive since it is not clear from the productivity indicator data whether the improvements are due to technology implementation or other changes in the organization. MST staff believes that the technology has assisted them in increasing their productivity by carrying more passengers during the same service hours with improved scheduling. It is recommended that this hypothesis be re-examined in Phase III.

  MST also pointed out that a productivity increase may not be an absolute indicator of service improvements since a decrease in productivity sometimes benefits their organization by helping them provide on-time service. For example, reducing the number of passengers on overcrowded buses can reduce dwell times at stops, and subsequently improve the schedule adherence of those buses.

- <u>Hypothesis: The project will result in an improvement in maintenance scheduling and planning.</u> This hypothesis is supported by the information provided by the maintenance department during on-site interviews conducted as part of the evaluation. MST staff believes that the MMS has enabled them to track daily maintenance activities such as inventory control, maintenance-workflow management, and fuel management. Other systems such as the ACS and video surveillance system assist MST by enabling them to review on-board system performance logs and by helping them monitor the quality of maintenance work (through reviews of recorded videos), respectively.

  The Team also wanted to evaluate the capabilities and impact of the remote diagnostics system implemented as part of the ACS. However, MST discontinued the remote diagnostics feature after initial use since the diagnostics were completely unreliable. MST was receiving an overwhelming number of false alarm messages which led them to ignore the remote diagnostics.

The secondary hypotheses for this evaluation are:

- <u>Hypothesis: The project will result in improved customer satisfaction.</u> This hypothesis still needs to be tested. Surveys will be conducted during Phase III to determine the improvements in customer satisfaction due to the technology deployments.

- Hypothesis: The project will result in an increase in ridership. The data provided by MST shows an increasing trend in ridership since 2003. However, this information does not support the hypothesis as it is not clear if the ridership increases have been due to just technology implementations.

  This hypothesis should be revisited during Phase III by asking questions of customers regarding the impact of technologies. For example, customers should be asked whether their willingness to use and the actual use of transit has increased since the technology implementation. The customer response will assist the Evaluation Team in determining the impact of technology in customers' willingness to ride MST.

- Hypothesis: The project will result in an improvement in driver and passenger security. The Evaluation Team obtained several anecdotal references that support this hypothesis. The general perception at MST is that security systems have helped them create a safer environment for MST riders and coach operators (the term used by MST to identify bus drivers). MST has posted placards on-board vehicles that inform riders that they are under video surveillance.

  The local police consider MST buses as "mobile surveillance units." MST's ability to provide video evidence of criminal activities that involve MST buses with the help of on-board cameras has helped them improve their relationship with the local police.

  The on-board security cameras assist MST in primarily capturing evidence of any criminal activity. Additionally, these cameras have continually assisted MST in reducing the number of insurance claims submitted by passengers (e.g., related to slip and falls). Also, the video evidence assists MST in protecting their drivers from being victims of false customer complaints.

- Hypothesis: The project will result in a reduction in the travel times of specific routes where TSP is deployed. This hypothesis will be tested during Phase III of the evaluation as MST has not yet implemented the transit signal priority.

- Hypothesis: The project will help reduce response time for incidents and emergency management. The hypothesis can be supported by information provided by operations and maintenance staff. However, the Team did not receive any quantitative estimates of improvements in response time.

  The availability of the ACS assists MST staff to track vehicle locations in real-time and enables them to send a supervisor to the accident site immediately. Also, MST drivers can select a specific text message from the list of canned messages on MDTs and send that to the dispatcher to notify operations that there has been an incident, and avoid making a voice call, if possible. Text messaging capability has helped MST reduce the voice radio traffic by 60 percent. Also, starting fall 2008, MST supervisor will be able to connect remotely to the ACS to obtain any additional information that is needed while responding to an incident.

  The ACS enables MST to provide and monitor evacuation services in the event of natural disasters such as the wildfires that happened during summer 2008. For example, during the recent wildfire event in Big Sur, MST was able to develop and manage task forces using MST vehicles through the use of the ACS.

Also, the number of incidents has been reduced in recent years subsequently contributing to reduced insurance premiums.

- Hypothesis: The project will result in a reduction in vehicle hours. The intent of this hypothesis was to test that the technology has assisted MST in reducing the number of revenue hours since 2003. Since annual revenue-hour statistics do not show a consistent increasing or decreasing trend, this hypothesis could not be supported. The number of revenue-hours decreased between 2003 and 2005, but an increasing trend can be seen since 2005. This inconsistency could be due to operational changes (e.g., addition of more trips to a route) implemented by MST throughout the evaluation timeframe. This hypothesis should be revisited in Phase III of the evaluation.

- Hypothesis: The project will reduce the number of customer complaints. This hypothesis cannot be tested completely as MST does not have a record of the number of customer complaints for the "before" and "after" cases.

  MST believes that the reduction in the number of complaints should not be an absolute indicator of improved customer service. They have noticed that the number of complaints have increased since MST developed an efficient process to track and respond to a customer complaint. It is evident that customers like to provide more comments and feedback only when they are assured of receiving a response.

- Hypothesis: The project will result in improved facility security. This hypothesis is supported by the facts and anecdotal references obtained during on-site interviews at MST. The physical facilities are equipped with cameras and the closed circuit television (CCTV) technology that enable the real-time video monitoring of facilities by the safety and security group. MST staff believes that the video monitoring capability has assisted MST in reducing vandalism activities and creating a more secure environment for MST riders waiting at transit centers.

  Also, MST is planning to control access to its facilities with a proximity card. MST will be able to secure its physical facilities (headquarters and the transit centers) by restricting entrance to only authorized employees. Since, as of August 2008, this card system had not been deployed, this hypothesis will be revisited in Phase III of the evaluation.

- Hypothesis: The project will establish a comprehensive reporting system. This hypothesis cannot be supported with the available information as the reporting process could not be evaluated "before" and "after" the technology.

  However, MST staff believes that they need to improve their current reporting. The standard reports provided by various deployed systems (e.g., ACS, MMS, FAMIS) do not necessarily provide the information needed by MST employees. MST has hired an outside consultant to conduct a needs assessment for reporting. Each MST business unit (departments) is providing input so that the consultant can design reports to best suit their needs using Crystal Reports, Microsoft Excel and other web-based reporting tools. This hypothesis will be retested during Phase III.

- Hypothesis: The project will result in reduced cases of false financial claims. MST provided several anecdotal references (see Section 3.3.2.2) that serve as evidence of financial savings due to the implementation and use of technologies, primarily the video surveillance system. The video playback component of the ACS also assists MST in responding to customer complaints related to late arrivals or departures.

The on-board cameras have helped MST save money in various false complaints and accidental damage claims from passengers. MST reported that they recovered $70,000 during fiscal year 2007. However, before the installation of the video surveillance system, their recovery was only in the order of $800- $1800. Also, MST had to pay $3 million in settlements due to lack of sufficient evidence which could have been mitigated with the help of an additional exterior camera on the bus.

Even though the Evaluation Team was not able to derive conclusions on the direct impact of technology for certain expected changes (e.g., increased ridership, improved on-time performance), anecdotal information obtained from MST staff has provided significant evidence to show that, so far, technology has made significant improvements in operations and planning. Generally, technologies have played a significant role in improving the efficiency of all departments as reported by the MST management. Improved efficiency has helped MST achieve cost savings as well. It is expected that even more benefits will be realized as these technologies are relied upon even more to perform specific operational and management functions.

Technologies have primarily helped MST operations by enabling them to track their vehicles in real-time and respond to incidents and emergency situations quickly. Also, HASTUS and the ACS along with other tools have helped MST improve their planning which has subsequently helped them in running better operations (e.g., improved on-time performance resulting from route changes and schedule adjustments). The impact of the video surveillance system is significant as well because it has created a safer rider environment and has enabled MST to defend themselves against lawsuit claims and reduce insurance related costs. The maintenance department has experienced benefits through the MMS as it assists MST in improving the workflow process and quality control.

The technology implementations provided an opportunity for MST to learn several lessons that will help them in future procurements. As MST plans to replace some of their systems (e.g., the ACS) with upgraded and better technologies, they believe that the prior deployment experience gives them enough confidence to procure from and negotiate with vendors, and manage the implementation of those technologies.

1 Introduction

1.1 Overview of the Monterey-Salinas Transit

Monterey-Salinas Transit (MST) is one of the three major transit providers in Monterey Bay area. MST was formed in 1981 after the merger of the Salinas Transit System with the Monterey Peninsular Transit. Currently, MST serves an approximately 280 square-mile area of Monterey County and Southern Santa Cruz County. MST provides service to the 352,000 residents of Monterey County. MST also provides curb-to-curb paratransit transportation services, RIDES, to the residents of MST service area who need specialized transportation. RIDES is operated by MV Transportation.

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In addition to the Monterey-Salinas area, intercity routes connect MST with the Santa Cruz Metropolitan Transit District. MST also provides rural transit service to Carmel Valley and seasonal service to Big Sur. Recently, MST has added express commuter routes to its service on two corridors: Monterey and San Jose, and Salinas and King City.

In addition to regular and express routes, MST operates trolleys that serve the area along the Monterey and Pacific Grove waterfronts.

MST recently reviewed and modified its routes based on recommendations from the Monterey Peninsula and Salinas Service Area Studies completed in 2005 and 2006, respectively.

MST operates its services from the following five transit centers or transfer centers located across its service area:

- City of Monterey: Monterey Transit Plaza;
- City of Salinas: Salinas Transit Center;
- City of Sand City: Edgewater Transit Exchange;
- City of Marina: Marina Transit Exchange; and
- City of Watsonville: Watsonville Transit Center.

MST serves 36 fixed routes that include approximately 1,250 bus stops. Table 1 provides information on specific operational characteristics of MST.

Table 1. MST Operational Characteristics

Category	Directly Operated Services	Contracted (Fixed Route and Demand Response)
Number of coach operators[2]	123	28
Number of road supervisors	9	3

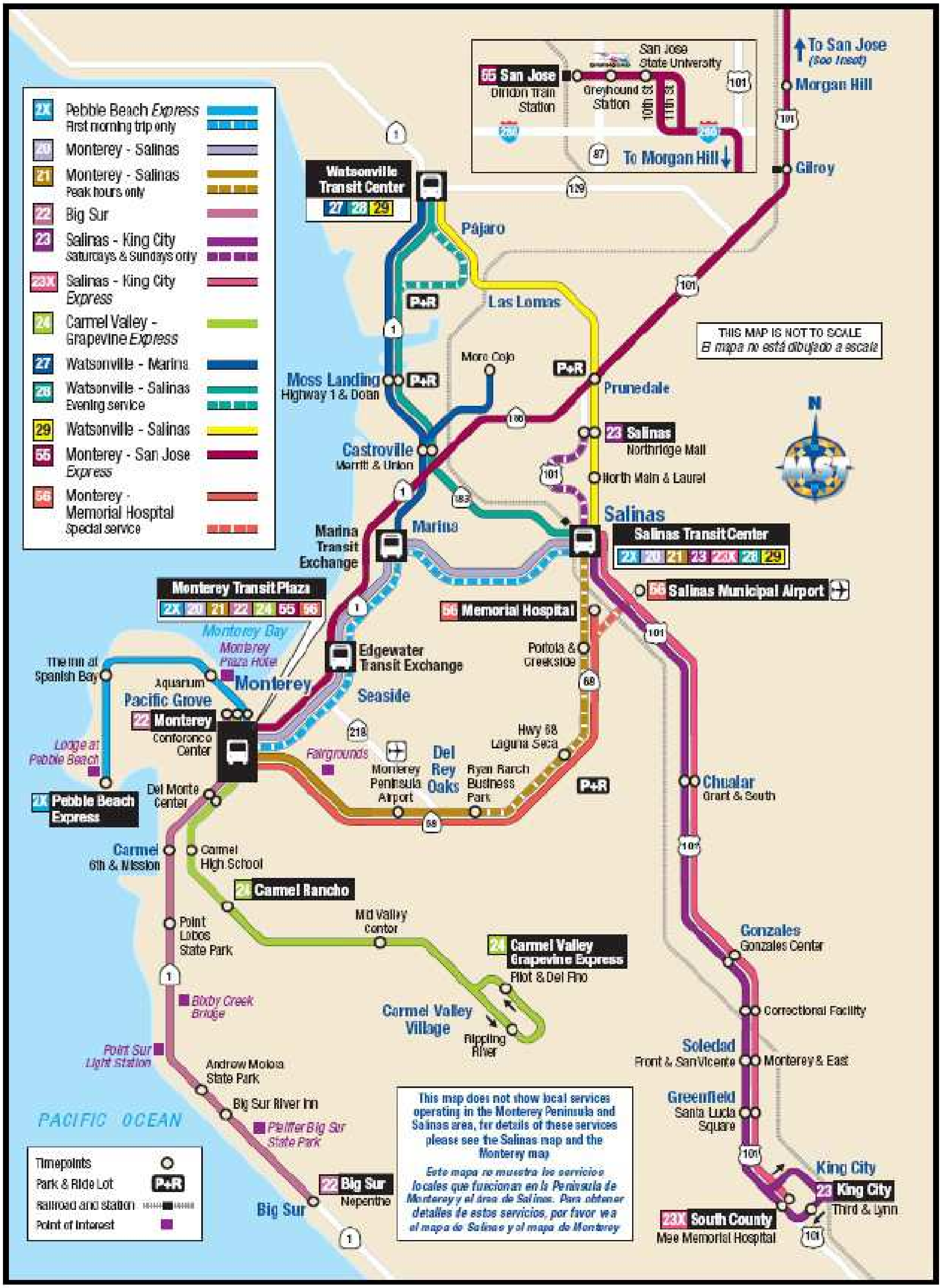
[2] "Coach Operators" is the term used by MST for bus drivers

Category	Directly Operated Services	Contracted (Fixed Route and Demand Response)
Number of dispatchers	4	3
Number of revenue vehicles	76	21
Number of non-revenue vehicles	31	Not applicable

MST operates approximately 3.2 million revenue miles and just under 210,000 revenue hours annually. Other operating statistics and performance measures are as follows for fiscal year 2007:

- Annual operating and capital budget = $22.1 million
- Passengers per revenue-mile = 1.5
- Annual boardings per capita = 13.89
- Operating cost per passenger = $4.34
- Passengers per revenue-hour = 23.4
- Operating cost per revenue-hour = $101.73

Figure 1 is a regional map of the MST service area.



Source: Monterey-Salinas Transit

Figure 1. Regional Map of MST Service Area

1.2 Monterey-Salinas Transit ITS Augmentation Project

Siemens VDO Automotive Corporation (now Continental Automotive Systems US) implemented the TransitMaster system at MST in October 2002 as part of a $3.5 million MST Advanced Communication System (ACS) project. The TransitMaster system was installed to provide MST operations with computer-aided dispatch/ automatic vehicle location (CAD/AVL) and digital voice/data communications. Later in 2006, a maintenance management system (MMS) was installed. Also, MST procured financial management and accounting software (FAMIS) in 2006. MST has plans to integrate the MMS with the FAMIS. They will not integrate the ACS with the MMS. In 2007, MST procured and installed on-board internet access system on buses serving commuter routes.

In fiscal year 2003, MST received Federal earmark funding for the implementation of the ITS Augmentation Project to address the following areas:

- Customer information and convenience;
- On-time performance;
- Route performance and cost;
- Automated passenger counting;
- Operational efficiency and management;
- Maintenance scheduling and management;
- Safety and security;
- Integration with the regional emergency services communication system; and
- Enhanced reporting.

Like many other transit agencies, MST was faced with challenges in keeping track of its fleet and personnel, monitoring the performance of its services, and complying with the Americans with Disabilities Act (in terms of providing next-stop and major intersection announcements). MST procured their Advanced Communication System (ACS) system, consisting of new radio and a GPS-based CAD/AVL system, to meet these needs. The ITS Augmentation Project continues to meet the additional needs of MST, such as providing a high level of safety and security both on-board and in transit facilities, providing passengers with real-time information and trip planning capabilities, facilitating the collection of passenger counts, and ensuring service reliability. In meeting these needs, one key element of the Augmentation Project is to ensure that all aspects of the ACS are fully integrated.

MST has completed the deployment of most of the ITS systems as part of the ITS Augmentation Project, with a few yet to be deployed (e.g., TSP and additional real-time information signs). The following sections describe the basic features and the deployment status of each of the technologies identified as part of the ITS Augmentation Project.

1.2.1 Passenger Counting

The implementation of a passenger counting system was accomplished using a technique that was different than what was originally intended. The agency has elected to gather passenger counting information by having MST coach operators record (via their MDT) the number of passengers boarding (see Figure 2).

MST coach operators do not enter any alighting data. Daily alighting figures are estimated based on the number of boardings. Also, alighting data is verified using information from on-board surveys[3] when National Transit Database (NTD) data is being collected.

Figure 2. On-board MDT

1.2.2 Automated Vehicle Announcements (AVA)

All vehicles are equipped with on-board light emitting diode (LED) dynamic message signs (DMS) and a public address system for making visual and audio next-stop announcements. These announcements are made per the ADA. Figure 3 shows DMS installed inside an MST vehicle showing a "stop requested" message. When a stop has been requested, the DMS alternates to a next-stop announcement message as the vehicle approaches a major stop, landmark or street-intersection.

1.2.3 Transit Management and Planning Software

The existing scheduling and runcutting software GSched was upgraded and replaced with HASTUS Scheduling Software from Giro, Inc in 2005. The Daily Dispatch and Attendance Management (DDAM) timekeeping module of HASTUS was purchased from Giro, Inc in 2007.

1.2.4 Surveillance System

As of August 2008, all MST revenue vehicles are equipped with digital cameras. MST completed the initial installation on 38 vehicles in 2003 and installed cameras on the remaining vehicles in 2007. These cameras are installed both on the interior and exterior of MST vehicles. The video is recorded by a digital

3 On-board surveys refer to the counting of the number of passengers boarding and alighting done by MST staff or a consultant.

video recorder (DVR) which is connected to the on-board cameras. The on-board DVR can store up to 72 hours of data. Data is overwritten once the DVR memory disk reaches its capacity.

The surveillance system has enabled MST to develop excellent relationship with the local police department by sharing video data when necessary.

Figure 3. On-board DMS for Making Visual Next Stop Announcements

1.2.5 Archived Data User Service

The implementation of the ACS has enabled MST to store, archive and retrieve historic logs of daily vehicle events. The data archived by the ACS can be exported and analyzed by MST planning and operations staff. MST staff utilizes Microsoft Access and Excel to analyze the archived ACS data.

1.2.6 Real-time Traveler Information

The DMS that provide real-time information were installed by MST at the Marina Transit Exchange and Salinas Transit Center in 2007. Additional DMS will be installed in 2008 at major bus transfer points, including downtown Monterey, the Del Monte Shopping Center, Northridge Mall and the Crossroads Shopping Village.

1.2.7 Transit Signal Priority (TSP)

MST has been negotiating with the City of Salinas and other jurisdictions to achieve consensus for the implementation of TSP along the proposed bus rapid transit (BRT) corridors. Currently, only the City of Monterey has approved the use of TSP. Thus, MST is not certain about the timing of TSP deployment (as of August 2008).

1.2.8 Integration with Translink[4]

MST had planned to implement smart card fare media on buses traveling to the Bay area, which is currently using the Translink smartcard fare payment system. MST runs eight buses on the long distance commuter route to San Jose. However, due to delays caused by institutional agreements between the vendor and agencies in the region, MST has decided not to use the same Translink fare media.

MST will be investing in a separate smart card fare payment system in the future by utilizing a grant received from the State of California. Please refer to Section 6.1.3 for further details on the future smart card fare payment system.

1.2.9 Improvements in MST website

Originally, MST planned to participate in the TakeTransit trip planner program offered by the Metropolitan Transportation Commission (MTC) in the San Francisco Bay Area. However, MST had discussions with Google, Inc. and decided to implement a regional trip planner for the Monterey-Salinas and Santa Cruz regions. After evaluating several other options, MST decided to deploy the Google Transit trip planner. As of August 2008, the beta version of the Google Transit trip planner was being tested using data generated from HASTUS. MST expects to “go-live” with the trip planner in Fall 2008. The Google Transit trip planner for MST will enable MST riders to plan regional travel.

Displaying the real-time location of buses on their website is not a high-priority requirement for MST since their customer service representatives do not receive a large number of calls requesting information on the real-time location of buses. However, MST is interested in surveying customers regarding their interest in using such a capability in the future.

Table 2 provides a summary of the current (as of August 2008) status of each technology deployment as part of the ITS Augmentation Project.

Table 2. ITS Augmentation Project Deployment Status

Technology	Deployment Status
On-board Passenger Counting	Completed in 2003
Automated Annunciation System	Completed in 2003
Upgrade of Transit Management and Planning Software	Completed in 2005
Digital cameras on buses and in transit centers	Completed in 2007
Archived Data User Services (ADUS)	Completed in 2003
Real-time Traveler Information System	Completed in 2007
Trip Planner	To be completed in 2008
Transit Signal Priority (TSP)	Deployment timeframe uncertain
Smart Card Payment System	Deployment timeframe uncertain

[4] Translink is a Contactless smartcard based fare collection system being implemented in the San Francisco Bay Area.

1.3 Overview of MST ITS Evaluation Project

The USDOT ITS Joint Program Office (JPO) established a National ITS Evaluation Program to determine the impacts of ITS deployments across the country. The objective of these evaluations is to document findings that can be used by a wide variety of external audiences such as planners, engineers, and managers. The results of these evaluations assist in the planning and implementing of future ITS projects with help of lessons learned from systems already implemented.

The USDOT/JPO selected the MST ITS Augmentation Project for an evaluation to be conducted by an independent Evaluation Team comprised of SAIC and TranSystems (referred to as the Evaluation team in this report). The two-fold purpose of this evaluation is to evaluate the use of archived ITS data for improving service planning and operations, and to evaluate the costs and benefits of implementing the MST ITS Augmentation Project. The ACS was evaluated along with the technologies that are part of Augmentation Project since these technologies were integrated with the ACS. Further, the ACS was evaluated since it contributes significantly to achieve the ITS Augmentation Project goals (e.g., on-time performance). Also, the Evaluation Team analyzed the impact of other technologies that were not procured with the Federal earmark funding (e.g., FAMIS and MMS) but have made significant contributions to improvements at MST.

The evaluation is being conducted in three phases. Phase I of the evaluation was an initial assessment of the implementation of the Augmentation Project by the Evaluation Team. This Phase was completed in October 2005 when the Evaluation Team submitted their Phase 1 findings to the USDOT JPO. These findings assisted the USDOT/JPO in deciding to proceed with a full evaluation of MST's Augmentation Project. Phase I results are not included in this Evaluation Report.

Phase II (this phase) focused on a "before" and "after" analysis of the technologies that have been fully deployed. Additionally, Phase II includes a "before" analysis of the technologies that are planned to be deployed in the future.

Phase III will consist of an "after" analysis of those technologies that are currently planned for development. The evaluation approach adopted for Phases II and III is discussed in Section 2 of this report.

1.4 Document Organization

The remainder of this Evaluation Report is organized as follows.

- Section 2 discusses the evaluation approach;
- Section 3 discusses the impact of the deployed systems and sub-systems on various departments at MST (e.g., Planning, Operations and Security);
- Section 4 describes the implementation challenges faced by MST during the deployment of ITS technologies.
- Section 5 identifies several lessons learned from MST's experience with the deployments;
- Section 6 discusses the technologies that are yet to be evaluated under Phase III; and

- Section 7 provides a summary of the results of the Phase II of evaluation. Also, this section provides recommendations for hypotheses that will be tested during Phase III.

2 Evaluation Approach

A kick-off meeting was conducted in Monterey, California, at MST headquarters on November 1, 2006 to begin preliminary discussions and lay the foundation for the overall evaluation process as discussed later in this section. The following steps were proposed for conducting the evaluation:

- Develop Evaluation Plan;
- Develop Test Plan;
- Collect data and conduct data analysis;
- Conduct on-site interviews at MST; and
- Prepare and submit final evaluation report.

The last four steps (i.e., data collection through the final report) were proposed to be conducted separately for Phases II and III of the evaluation.

2.1 Evaluation Plan

2.1.1 Evaluation Phases

USDOT-sponsored ITS evaluations are traditionally divided into phases. During Phase II, the Evaluation Team collects data before the technologies are deployed and summarizes the “before” data in a Phase II Report. During Phase III (after the approval of Phase II results), the Evaluation Team collects the “after” data once the technologies have been deployed, and presents the findings of the before and after analysis in a Phase III Report. In the case of the MST ITS Augmentation Project, many of the technologies are already deployed, presenting the Evaluation Team with an opportunity to document the findings of the before and after analysis without having to wait for the technologies to be deployed. However, there are a few project components that are not yet deployed, namely TSP, Google Transit and smart card fare payment projects. To enable the timely publication of results of the evaluation of technologies already deployed, the Evaluation Team proposed that the scope of both phases be conducted in the following manner:

- **Phase II:** The “before and after” analyses were performed for those technologies that have been fully deployed and are operational. For those technologies that do not have a definite deployment frame, only the “before” analysis was performed. The Phase II Report has been prepared with results from these analyses (“before and after” analysis for implemented technologies, and “before” analysis for planned technologies).

- **Phase III:** This phase will consist of evaluating the technologies that will be deployed in the future. The Evaluation Team will collect the “after” data following the implementation of the new technologies. For the evaluation of the new technologies, the ITS-JPO will determine whether or not Phase III will be conducted after examining the results of the Phase II analysis.

After the approval of Phase II, the Evaluation Team will perform the following Phase III activities:

- Collect data for the “after” analysis following the implementation of the new technologies;

- Perform data analysis and test the hypotheses associated with Phase III technologies;
- Develop the Draft Evaluation Report for Phase III and provide the report to FTA/FHWA for review and comment; and
- Incorporate FTA/FHWA comments, revise, and finalize the Final Evaluation Report for Phase III and submit to FTA/FHWA for final review and approval.

2.1.2 Evaluation Hypotheses

The evaluation hypotheses and measures of effectiveness (MOEs) were developed in the initial phase of this evaluation project. The hypotheses that were submitted and approved in the Evaluation Plan were identified in two distinct categories: “Key hypotheses” and “Secondary hypotheses.”[5]

Both key and secondary hypotheses were tested in the in Phase II based on test procedures identified in the Test Plan. Section 7 describes results obtained from test of these hypotheses.

The key hypotheses for this evaluation are:

- The project will result in a reduction in operations and planning costs and improved service planning.
- The project will result in improved on-time performance of MST operation
- The project will result in an increase in the reliability of services
- The project will enhance system productivity
- The project will result in an improvement in maintenance scheduling and planning

The secondary hypotheses for this evaluation are:

- The project will result in improved customer satisfaction
- The project will result in an increase in ridership
- The project will result in an improvement in driver/ passenger security
- The project will result in a reduction in the travel times of specific routes where TSP is deployed
- The project will help reduce response time for incidents and emergency management
- The project will result in a reduction in vehicle hours
- The project will reduce the number of customer complaints
- The project will result in improved facility security
- The project will establish a comprehensive reporting system.
- The project will result in reduced cases of false financial claims

[5] Secondary hypotheses are those that address goals that are relatively less significant in improving daily operations at MST in comparison to key hypotheses.

Please refer to Appendix A for a detailed list of measures of effectiveness (MOEs) for all hypotheses.

The evaluation of these hypotheses can be categorized based on their contribution to individual operational departments at MST. Hence, the Phase II evaluation was conducted by studying each of the following topics:

- Transit Planning and Operations
- Maintenance and Incident Management
- Safety and Security
- MST Reporting Capabilities
- Finance
- Customer Service

The preceding categories were defined by considering the complexities of the evaluation based on: the MST goals for technology implementation, the nature of data analyses for this evaluation, and the types of data and data collection methods needed for analyses.

The hypotheses related to the TSP, real-time Information, smart card payment, trip planner and customer satisfaction will be tested in Phase III of the evaluation.

2.2 Test Plan

2.2.1 Data Collection

Phase II of the evaluation project required collecting data for both quantitative and qualitative analyses. Archived data from the ACS was collected for the time period April 15 to May 31 for each year from 2003 through 2007 to test the hypothesis related to on-time performance (see Section 3.1.1.1.1 for details). In addition to the ACS data, information such as operational statistics (e.g., vehicle revenue-miles and passenger-miles), cost and revenue data, information on performance measures, and accident or incident statistics, and financial claim/recovery data was collected to test other hypotheses.

In order to collect additional information, especially for the qualitative analysis, the Evaluation Team conducted several interviews during a two-day on-site visit at MST in August, 2008. These interviews were conducted with representatives from planning, operations, finance, maintenance, customer service, management, safety and security, and information technology. Please refer to Appendix C for a detailed list of questions asked in these interviews.

2.2.2 Analysis

A quantitative analysis was performed on ACS data to calculate on-time performance of MST vehicles for the selected time period. Since on-time performance measurement standards were changed by MST during the selected time period (see Section 3.1.1.1.2), the Evaluation Team measured on-time performance based on a new MOE. The on-time performance was measured based on the positive deviation (in number of minutes) of the actual arrival time from the scheduled arrival time. A detailed approach for this analysis is discussed later in this report (see Section 3.1.1.1.2). Also, the annual trends for other statistics (e.g., ridership, revenue, productivity and accidents) have been presented and explained in later sections of this report.

In addition to performing quantitative analysis, a qualitative assessment of the impact of technologies on daily activities of all MST departments was performed. The qualitative analysis was conducted based on information obtained from MST staff during the interviews conducted in August 2008.

Section 3 summarizes preliminary findings obtained from data analyses and on-site interviews to describe the impact of various technologies on MST operations.

3 Impact of Technology

3.1 Impact on Transit Planning and Operations

The Evaluation Team determined that there have been significant improvements in daily operations and planning activities since the implementation of the ITS technologies at MST. These improvements can be attributed directly to the use of the technologies and tools in both departments.

The following technologies are being used by the planning department at MST:

- HASTUS scheduling system;
- The ACS;
- Video playback system;
- ArcView geographic information system (GIS); and
- Microsoft Office products (e.g., Microsoft Excel and Microsoft Access).

The operations department uses the following technologies in addition to the above technologies:

- HASTUS-DDAM, the timekeeping module of HASTUS; and
- Trapeze Pass and Mentor-Ranger on MST RIDES (paratransit system operated by MV Transportation, a contractor)

HASTUS assists MST in preparing fixed route schedules and daily driver assignments. The DDAM module of HASTUS allows MST to track driver attendance with respect to assigned schedules. These systems are installed in the Communications Center[6] (see Figure 4).

The ACS system is primarily accessible in the Communications Center but can be accessed remotely over the MST virtual private network (VPN) by authorized staff. The ACS system includes a voice and data communication system (see Figure 5 for a photograph of the radio equipment in the Communications Center), a performance monitoring screen, and a real-time vehicle tracking screen (see Figure 6).

[6] "Communications Center" is the term used by MST for their dispatch center.

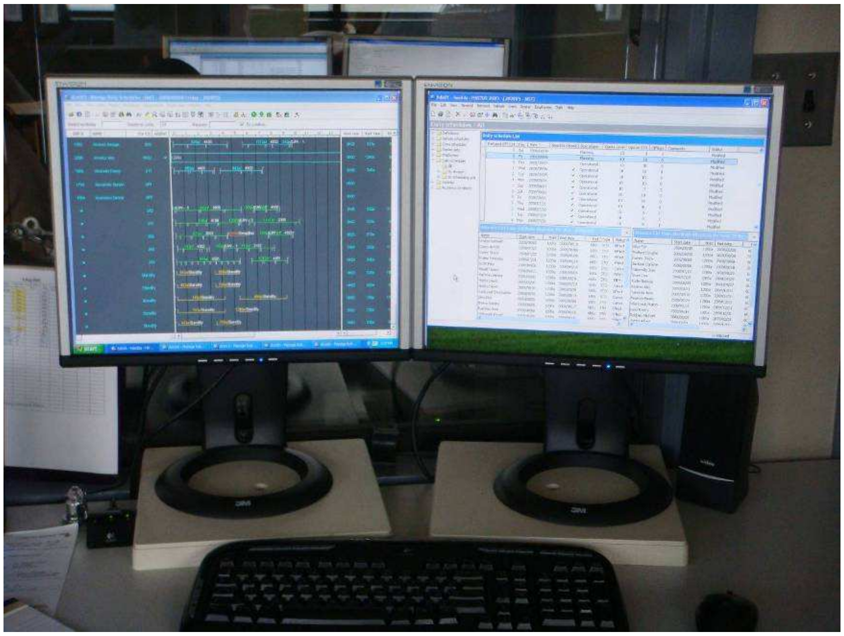


Figure 4. HASTUS Scheduling and DDAM Workstation in the Communications Center

Figure 5. Radio Equipment in the Communications Center

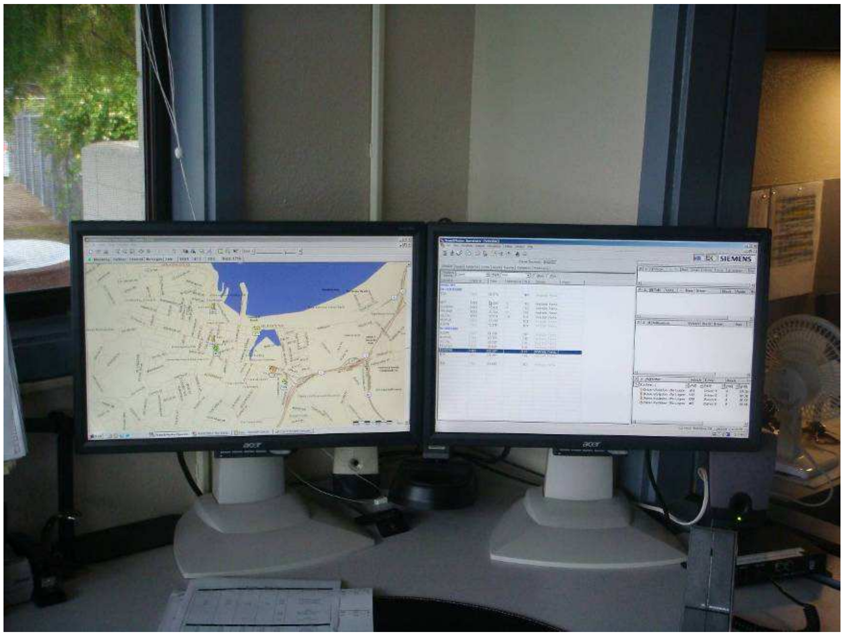


Figure 6. The ACS Workstation in the Communications Center

The ACS assists MST in daily operations by providing various capabilities to manage its fleet and coach operators in real-time. The following features of the ACS have been critical in improving operations at MST:

- Real-time Tracking of Vehicles: The coach operators and dispatchers receive schedule adherence warnings when the vehicles are running early or late based on a configurable threshold.

- Text messaging: Both dispatcher and coach operators send data messages to each other as needed.

  The store and forward feature of the ACS provides the capability of sending messages to an employee (via their ID number) from a dispatch workstation. These messages pop up when the employee receiving a message logs onto a workstation.

- Covert alarms: The coach operators can send emergency alarm messages to the dispatch center. MST reports that covert alarms typically occur once or twice a month. Sirens go off at the Communications Center when covert alarms are received.

- Automated Vehicle Announcements (AVA): The AVA system (with support from the ACS) makes visual and audible announcements at major stops and intersections.

- Route Adherence Monitoring: The dispatchers can monitor vehicles that stray from their route using the ACS.

- ACS System Control Log: The control log provides a record of daily events and can be searched using a text/keyword search feature.

- Reporting: The ACS provides several standard reports. Along with the standard reports, the ACS system provides several monthly summary reports which are used to provide summary information to the MST Board.

- Archived Data: The ACS provides data for review by the planning staff as needed. The planning department exports and analyzes archived data using external tools (e.g., Microsoft Excel).

  Also, archived data is used for planning studies. For example, the comprehensive operational analysis study done for the Salinas area in 2006 used data from the ACS.

The ACS provides a playback feature to review vehicle operation at desired time durations in the past. However, this feature is not used much by the planning department. Rather, the planning staff relies on data exports from the ACS for manual review and analysis of operational data with the help of Microsoft Excel and Access tools.

The AVL playback feature, however, has been very helpful to the operations department. The capability to review vehicle activities within a given time period allows operations staff to investigate customer complaints about early or late arrivals and departures of MST vehicles. Before the implementation of this feature, MST could not validate customer complaints regarding vehicles not arriving or leaving the stop on time (e.g., when customers referred to their own watches). Further, this feature assists investigating situations in which MST may have a valid complaint against a coach operator. MST has trained all its coach operators to use the time displayed on the MDT to avoid any conflicts with other time sources.

3.1.1 Operational Data Collection and Analysis

3.1.1.1 AVL Data

3.1.1.1.1 Data Collection Approach

During the data collection, it was determined that the ACS database was too large to perform an analysis of data for all routes even within a specified time period. Therefore, the Evaluation Team identified the key factors that would help reduce the size of data to be analyzed, while ensuring the integrity of the analysis. It was decided that the data that would be collected and analyzed reflect the following factors:

- A “meaningful” subset of the MST route system;
- The “most appropriate” time period; and
- The “most appropriate” data fields.

The Evaluation Team reviewed the COA study reports prepared in 2005 and 2006 to identify an initial list of routes that had operational issues. Then, the Team met with MST staff to select a list of routes and the timeframe for which the data would be collected. It was decided that Routes 4, 5, 9, 10, 11, 20 and 24 would be the most appropriate routes for the Monterey Peninsula area, and that Routes 41, 42 and 20 would be the most appropriate routes for the Salinas area. This group of routes was selected as these routes carry nearly 80 percent of all MST system riders. Also, these routes have not experienced a significant shift of riders to other MST routes since the installation of the ACS.

It was then decided that the data for all identified routes would be collected for the time period mid-April to the end of May for years 2003 through 2007. This decision was based on the fact that the ridership during this time period does not experience great fluctuations, or unusual high or low ridership due to events such as holidays and school closures or openings.

The data was collected using a Microsoft Access database and then was exported into Microsoft Excel spreadsheets for performing on-time performance analyses. Existing and customized analysis tools (e.g., pivot tables and Visual Basic Macros) were used to conduct the analyses.

3.1.1.1.2 Data Analysis Approach

During the data collection phase, the Evaluation Team discussed with MST the effect of changes in on-time performance standards at MST during the selected time period of the analysis.

Prior to implementing the technology in 2002, MST used a standard of seven minutes or more to indicate a late trip. After the technology implementation, however, MST began using a standard of three minutes or more as being late. The standard was further changed in 2006 to be five minutes or more. Based on this change in the definition of a late trip, the Evaluation team used the following separate trends for on-time performance:

- From 2003 to 2006: three minutes or more is defined as “late;” and
- From 2006 to the present: five minutes or more is defined as “late.”

The Evaluation Team calculated on-time performance statistics using the above standards but the results were not conclusive. Even though the Team noticed improvements in the on-time performance since the technology implementation, the reasons for the improvements were not obvious (i.e., ACS implementation or change in on-time performance standards). Hence, the Team decided to use an indicator of on-time performance, which is the deviation of actual arrival times from the scheduled arrival times (in number of minutes). The term “lateness” in this document refers to this deviation, which is the number of minutes after the scheduled arrival time.

Please refer to Section 3.1.2.2.1 for the detailed analysis using lateness, rather than on-time performance. Generally, the results were found to be inconclusive due to an inconsistent pattern of lateness. It was concluded that the inconsistent pattern in lateness was due to data issues in the ACS (please refer to Section 3.1.1.2 for details). Later, this problem was confirmed during on-site interviews with MST staff.

3.1.1.2 Data Issues

3.1.1.2.1 Issues Encountered during Data Analysis

The data collected from the ACS to conduct the on-time performance analysis was found to have several issues that yielded inconclusive results. These issues were mainly due to missing or unusually high values of vehicle arrival time.

There was missing data for actual arrival times for all of the selected routes. The trend analysis showed that data were substantially missing in the initial year of implementation in 2003 and after the service change in 2007. Table 3 shows the percentage of missing arrival time data. The analysis showed that the missing data had some correlation with the inconsistency seen in the trend for on-time performance.

Table 3. Percentage of Missing Arrival Time Data[7]

Routes	2003	2004	2005	2006	2007
4	39	7	4	3	45
5	37	6	7	6	37
9	32	4	2	2	1
10	37	4	3	2	1
20	46	9	8	17	26
24	42	18	15	20	46
41	47	9	5	14	10

Also, the Team found data with unusually high values for arrival times (e.g., 180 minutes) for some routes that resulted in inconsistent trends for lateness. This outlying data was excluded from the data analysis (which is described in Section 3.1.2.2.1). Due to the characteristics of the routes, the Evaluation Team decided to ignore lateness values higher than 30 minutes, since anything beyond 30 minutes was likely erroneous.

3.1.1.2.2 MST Staff Input on Data Issues

The Evaluation Team discussed the preliminary findings related to on-time performance with the MST staff during the August 2008. MST staff provided the following facts that helped in explaining the results obtained from the analysis:

- Unreliable ACS data for 2003: MST started using the data in 2004 since the system was not stable at the beginning. For example, MST encountered an instance when a bus was shown 45 minutes late on the ACS performance screen even though the vehicle was displayed at the correct location on the AVL screen. MST believes that the data generated by the ACS system in 2003 was erroneous due to reasons such as incorrect route and timepoint surveys, incorrect setup of arrival zones, and lack of differential correction of the GPS values.

- Changes in Routes 4 and 5: MST implemented a schedule-change in January 2007 which resulted in a significant change in Route 5. Further, both Routes 4 and 5 were contracted out in January 2007 and MST believes that these routes were not resurveyed. The contracted routes running in Carmel had problems receiving correct GPS values due to bad coverage.

- Fare Change: Fares were changed in 2005 (increased by $0.25 for each regular ride) and 2006 (increased by $.0.25 for each transfer) which could have resulted in "reboundimpact"[8] on the ridership. It is suspected that a reduction in ridership (due to rebound impact) could have resulted in better on-time performance due to shorter dwell times at stops. Also, there could have been some impact on the on-time performance of routes due to longer dwell times at stops if coach operators had to explain the change in fares to the riders.

[7] While the heading of each column is an analysis year, the data was analyzed only for a specific timeframe (mid-April to the end of May) within each analysis year, as discussed in Section 3.1.1.1.1.

[8] Increases in fares often result in a reduction in ridership. This phenomenon is called rebound impact.

- Change in Arrival Zones/Timepoint Boundaries: Arrival zones were adjusted for certain routes in 2005 as arrival zones were originally setup incorrectly in the ACS system due to the incorrect surveying of those routes.

In addition to the above mentioned major changes, MST reported that the following changes (related to the routes selected for analyses) could have impacted the analysis results:

- Route 11 did not exist until May 2004. Also, AVL data could not be collected for Route 11 in 2005 as there were problems in the ACS system with Route 11.

- Route 42 did not exist as a separate route until September 2004. Prior to 2004, Route 41 had two branches A and B. The B branch became Route 42 in September 2004.

- Route 24 got converted into an express route in 2007. This change would have impacted on-time performance of this route in 2007.

- Routes 4 and 5 used to be interlined until 2006 as people used to transfer and go downtown by connecting to Route 9 and 10, which are interlined as well. Interlined routes could result in inconsistent on-time performance as vehicles serving these routes could face "bus bunching"[9] problems.

- A large number of cancelled trips were reported for Route 20 in FY 2007.

- It was found that the on-time performance on Routes 20, 24 and 41 got worse in terms of on-time performance after resurveying conducted in 2006.

3.1.1.3 Other Data

In addition to AVL data, other information resources were collected to test the hypotheses related to COA studies, ridership and productivity measures.

3.1.2 Findings

3.1.2.1 Impact on Comprehensive Operational Analysis (COA)

MST has noticed that the COA studies conducted after the technology implementation (e.g., Salinas Area COA study in 2006) have taken less time to complete as compared to earlier studies.

The accuracy of the analysis results obtained from these studies is also more reliable as compared to earlier studies (e.g., COA study in 1999). Due to the availability of ACS, now MST has access to more reliable and larger volume of data for analyses. MST can respond to the data needs of its consultants in a better and timely matter. Earlier MST had to hire temporary staff to meet the data collection needs for COA studies.

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[9] Bus bunching occurs due to uneven spacing between buses serving different or same routes while running on the same corridor. This scenario may result in inconsistent dwell times at a stop for bunched vehicles.

The availability of the ACS provides the flexibility to consider different scenarios for operational analyses (e.g., seasonal ridership and monthly ridership). MST believes that such flexibility is very useful, especially for analyzing seasonal patterns (e.g., patterns of ridership and the on-time performance) in their system.[10]

The accuracy and reliability of the ACS data assists MST in defending information that is presented to the Board of Directors and the general public in implementing recommendations of COA studies. Before the ACS implementation, MST could not provide enough information to support Board requests. For example, the service improvement plan proposed after the COA study in 1999 faced a lot of questions and concerns during the public meetings. It was challenging for MST to defend those results since the data was collected manually and could not be validated using additional data. Also, the validation process would have demanded extra resources in terms of time and money. Now, the ACS can provide additional data if needed. For example, in 2006, MST proposed to eliminate service on Route 21 due to poor performance and was able to defend their proposal based on an analysis conducted using archived ACS data.

Even though MST believes that the cost of data collection has been reduced as a result of the ACS, they do not have any quantitative information to show the actual change in the cost of conducting COA studies.

3.1.2.2 Impact on On-Time Performance

3.1.2.2.1 Results of Data Analysis

The ACS data was analyzed to determine the impact on lateness (considered as an indicator of on-time performance in this data analysis). The analysis was divided into two steps. First, lateness per timepoint was calculated by summing the number of minutes late per timepoint for each trip, and then dividing by the number of timepoints. Second, the average lateness per trip was calculated by dividing the total lateness per timepoint (across all the trips) by the total number of trips for a given scenario.

The data analysis was conducted to calculate three distinct measures of effectiveness: average lateness by route, average lateness by day of week and average lateness by time of day. However, the results of this quantitative analysis were found to be largely inconclusive due to problems identified with the data, as well as due to service and operational changes that were made at MST during the analysis timeframe.

Generally, the results did not show a clear trend in average lateness over time for the selected timeframe and routes. Figure 7 and Figure 8 show the results of the data analysis for the selected routes. The results are broken down by direction - average lateness was analyzed separately for inbound and outbound directions.

In several of the routes, the analysis showed that there was a change in average lateness from 2003 to 2004, which may be an indicator of the impact that the ACS had on operations. However, it was found that the average lateness fluctuates in the following years in some cases (further details can be found in Appendix B). For each dataset the Team also calculated the standard deviation. In most cases, the datasets were found to have high standard deviations (e.g., greater than two minutes per trip) for the evaluation timeframe.

[10] MST ridership is the highest in the summer season due to tourism and is the lowest during the school season.

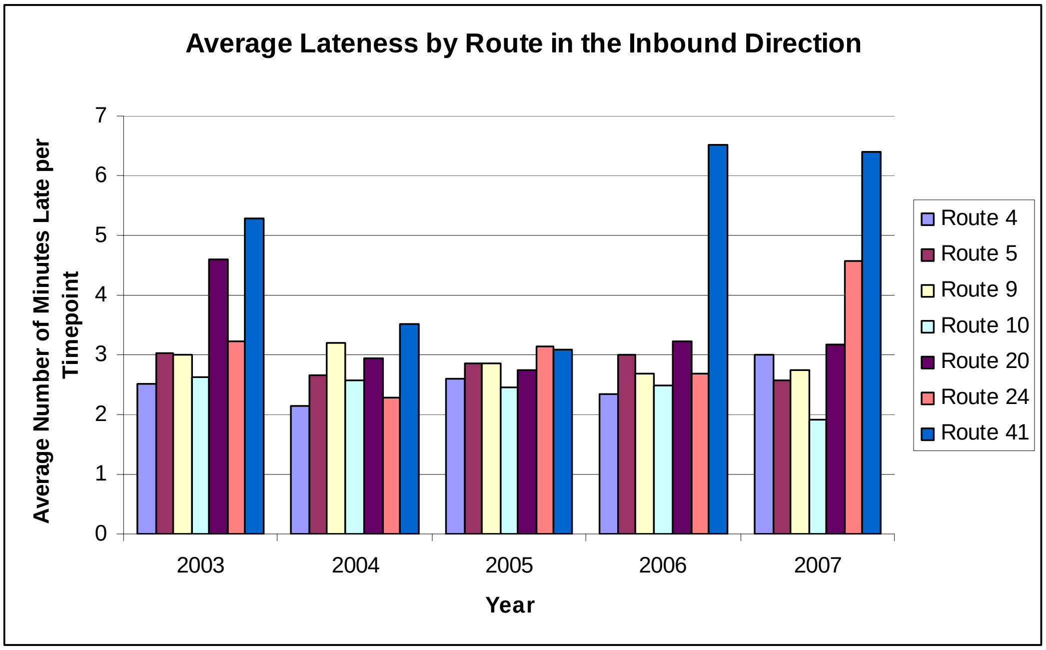

Figure 7. Average Lateness by Route in the Inbound Direction

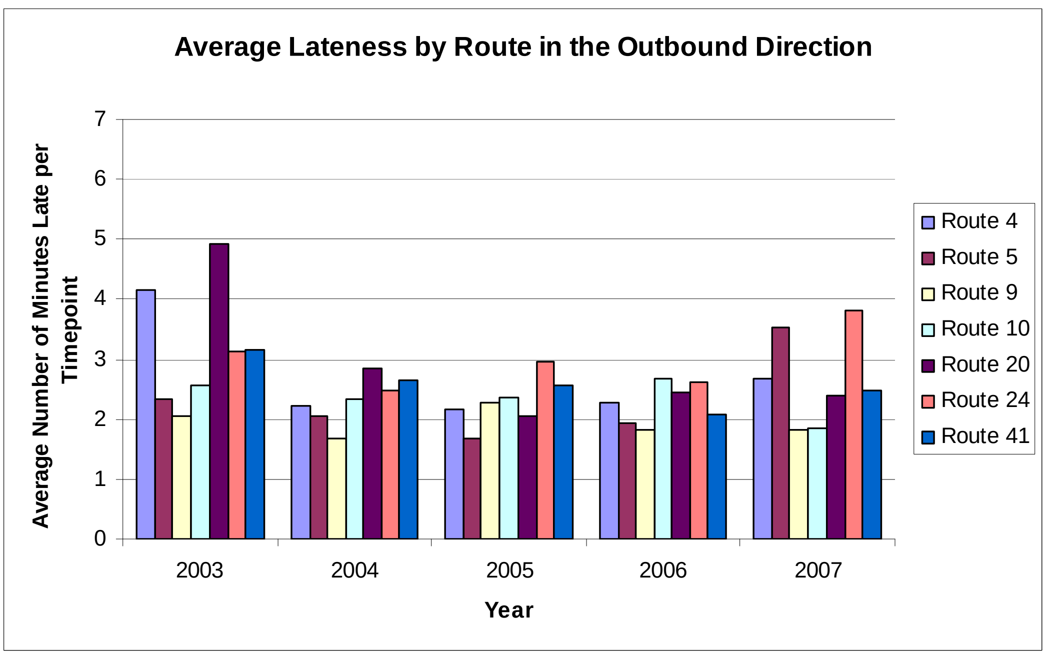

Figure 8. Average Lateness by Route in the Outbound Direction

Since high vehicle traffic during peak hours (5 to 10am and 4 to 8pm) can impact the on-time performance of MST buses, the data was analyzed to review average lateness during off-peak periods to see if there is any change over time. Figure 9 and Figure 10 show the change in average lateness during off-peak periods on weekdays for inbound and outbound trips for each route. Again the results did not show a clear trend in average lateness over time for the selected timeframe and routes.

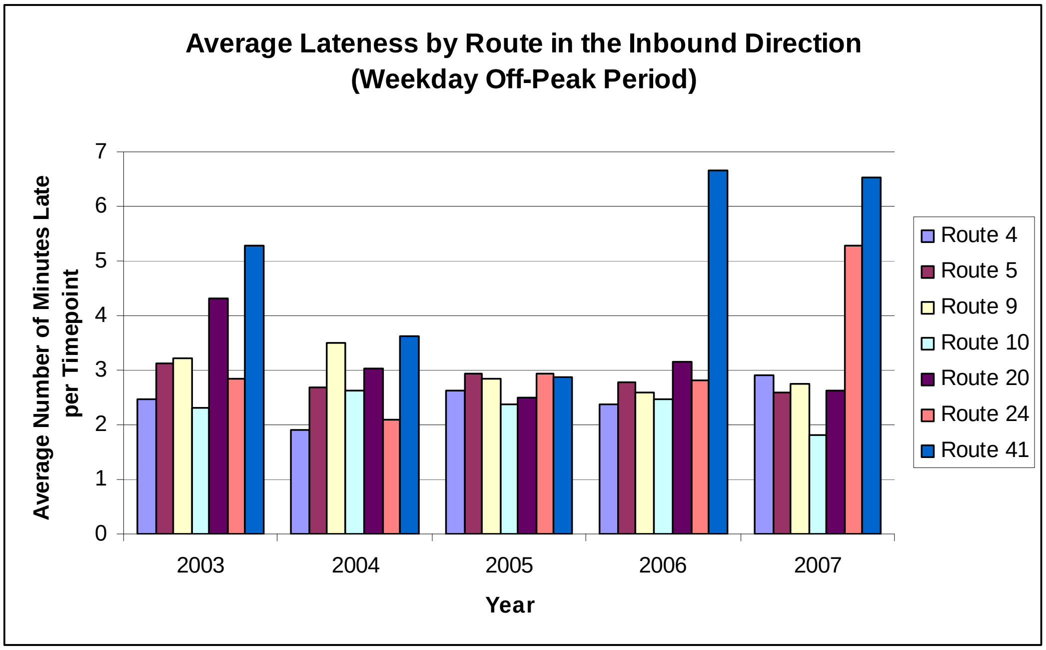

Figure 9. Average Lateness for the Inbound Direction on Weekday Off-Peak Periods

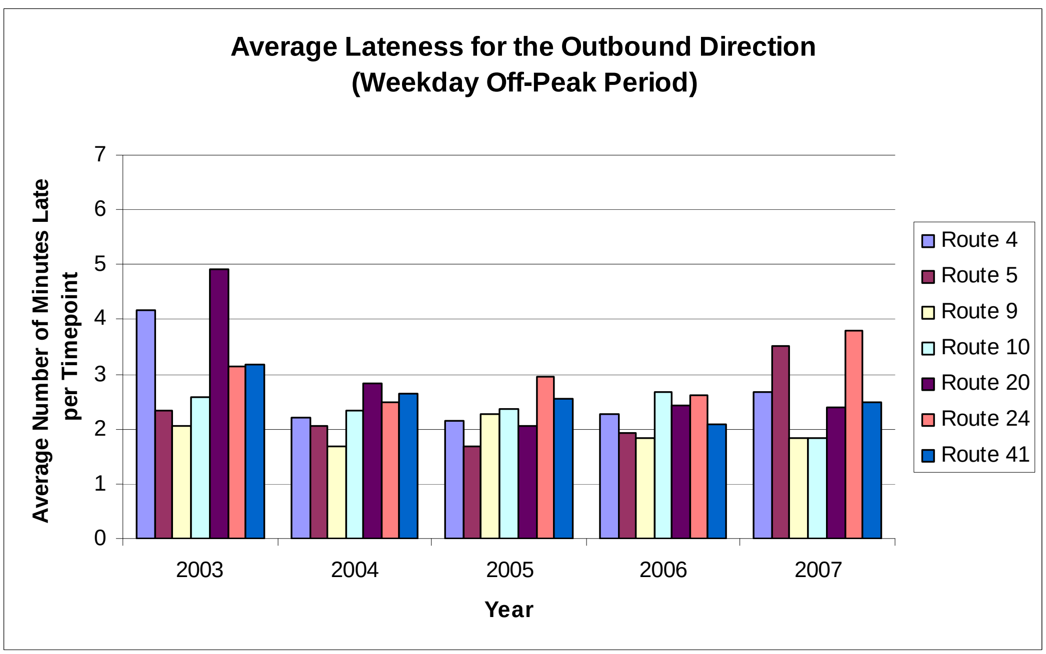

Figure 10. Average Lateness for the Outbound Direction on Weekday Off-Peak Periods

Further, average lateness was analyzed separately for weekdays and weekends. The purpose of analyzing this was to review any fluctuations in average lateness on weekends since the on-time performance of weekend trips can be impacted less by external factors in comparison to weekday trips (e.g., less commuter traffic). Figure 11 and Figure 15 show that, as with weekdays, there is no clear trend in lateness over time.

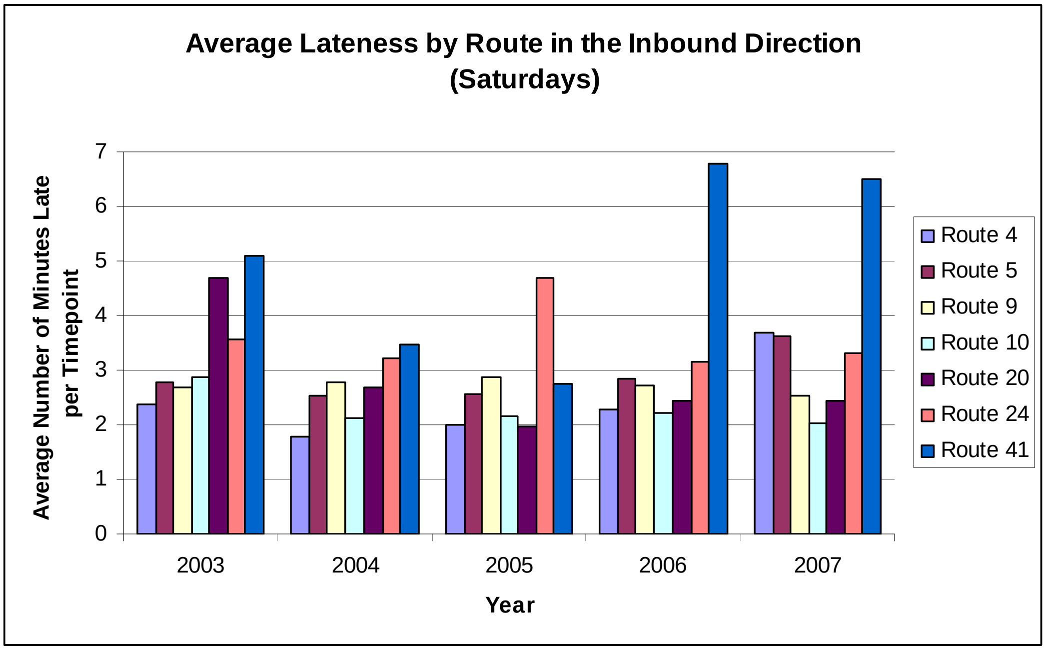

Figure 11. Average Lateness for the Inbound Direction on Saturdays

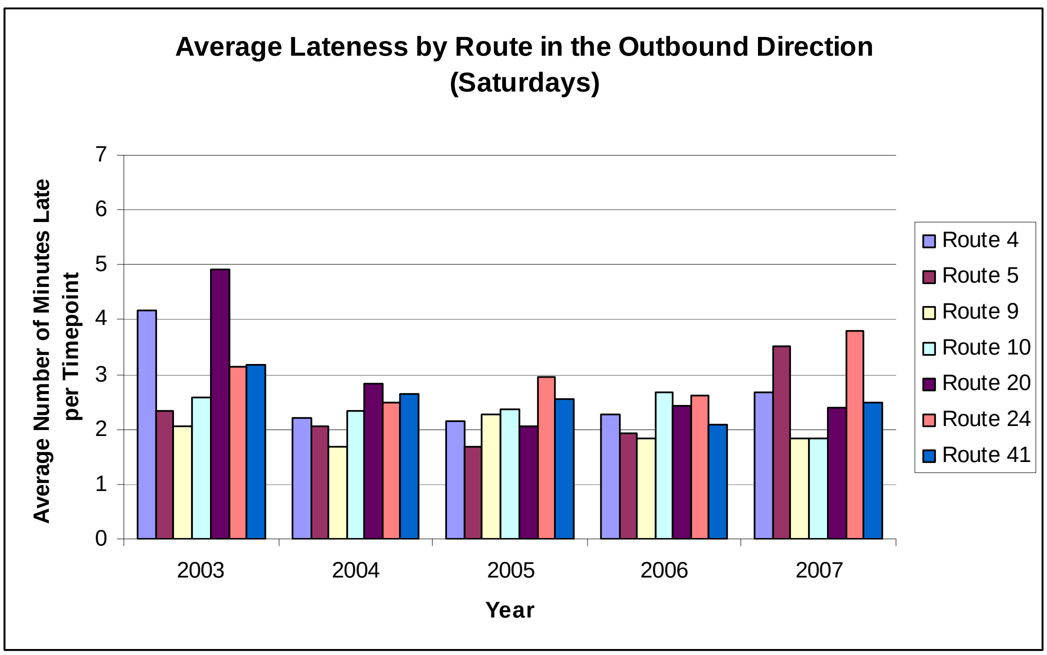

Figure 12. Average Lateness for the Outbound Direction on Saturdays

Since the results do not show any obvious trends (e.g., high lateness in the peak period), it is possible that service and operational changes at MST may have contributed to the fluctuation in average lateness. It is challenging to conclude that the improvements seen in the data were mainly due to the implementation of the ACS since MST had implemented other operational changes throughout the evaluation timeframe (e.g., schedule changes in 2007, change in fares in 2006 and 2007, and timepoint adjustments in 2005).

Additional external factors such as construction detours or fluctuations in traffic volume could have contributed to this inconsistent trend as well.

While the inconclusive results can be attributed to external factors, the results were largely influenced by the issues associated with the dataset obtained from MST. MST reported that data generated in 2003 and 2004 by the ACS is not accurate enough and is known to have some issues as mentioned earlier (e.g., missing arrival times). Details on the other data related issues that may have contributed to these results have been discussed in Section 3.1.1.2. An additional data related issue leading to these results could be the low sample size (12 percent).

However, the results revealed some interesting trends on average lateness. For example, the average lateness for Route 4 was higher for the inbound direction as compared to the outbound direction for 2007 (as was shown in Figure 7 and Figure 8). MST said that this issue could be due to the contracted operation of these services. Currently (as of August 2008), MST is aware that the contracted routes are facing challenges regarding maintaining on-time performance.

3.1.2.2.2 MST Staff Interviews

MST believes that the process of tracking on-time performance has become more efficient since the implementation of the ACS. Prior to the ACS deployment, the on-time performance was determined manually by supervisors by checking vehicle performance against timepoints. Now this process is automated in the ACS system. The ACS tracks vehicle on-time performance at every timepoint and alerts coach operators, dispatchers and supervisors as needed.

Initially, there were issues with the data generated by the ACS system, but this system has improved over the past few years and has become more reliable in reporting on-time performance. Immediately following the ACS deployment, only 78 percent of timepoints were correctly defined in the ACS system. This problem was due to errors generated in surveying of routes and was corrected after resurveying those routes in 2004. The routes were initially surveyed by the ACS vendor. After obtaining proper training, MST conducted the surveys again themselves for the routes with of the highest volume of missing information. Resurveying has helped MST reduce the amount of the missing data in the ACS. Consequently, the ACS has been collecting better on-time performance data for MST routes since the resurveying was completed.

Along with resolving issues related to resurveying, MST had to learn a lot about field conditions for setting the thresholds for on-time performance. The change in the on-time performance threshold in 2006 has helped MST in improving the percentage of their on-time performance. These thresholds for early and late arrivals were recommended by the COA study conducted by MST in 2005.

Generally, MST believes that the ACS has helped the agency to monitor and improve its on-time performance in recent years. They have noticed that the system wide on-time performance has improved since the implementation of the technologies. Figure 13 and Figure 14 present the system wide on-time performance statistics measured in FY 2004 and 2007, respectively. It is evident from these charts that MST’s on-time performance was more than 80 percent across the fiscal year 2007, with monthly average on-time performance being approximately 84 percent. Earlier in FY 2004, the monthly average on-time performance was only 74 percent. However, it is not evident from these charts that improvements have been due to the change in on-time performance standards or technology implementations. The impact of the change in early and late arrival thresholds on on-time performance standards discussed in Section 3.1.1.1.2 could be the reason behind this improvement.

The ACS has enabled MST to make coach operators more accountable. Now, reports can be generated in the ACS related to operator performances. Hence, the coach operators are aware that they will be held accountable for early or late departures. The on-time performance compliance reports for operators are provided routinely to supervisors who can be pro-active in monitoring the vehicles that are operated by specific coach operators.

MST believes that they have achieved significant travel time savings since the technology implementation but they do not have any quantitative information to support that claim. However, the results of the recent COA studies in 2005 and 2006 show some travel time savings. MST has been focusing on reducing travel time to some of their destinations by analyzing ACS data. They have already introduced certain express bus services (e.g., Seaside to Carmel). These changes have resulted in increased ridership and decreased travel times along those routes.

MONTH	TIME POINT COUNT	DELAYED ARRIVALS 3 + MINUTES	ON-TIME PERFORMANCE
July	58,224	15,379	73.59%
August	88,380	25,442	71.21%
September	60,611	17,083	71.82%
October	83,889	25,222	69.93%
November	75,735	20,252	73.26%
December	80,237	18,137	77.40%
January	77,264	16,484	78.67%
February	79,872	18,405	76.96%
March	79,751	20,703	74.04%
April	84,258	22,544	73.24%
May	88,240	23,606	73.25%
June	**94,703**	**22,256**	**76.50%**
TOTAL	951,164	245,513	
Monthly Average	79,264	20,459	74.15%
YTD Comparison	951,164	245,513	74.19%

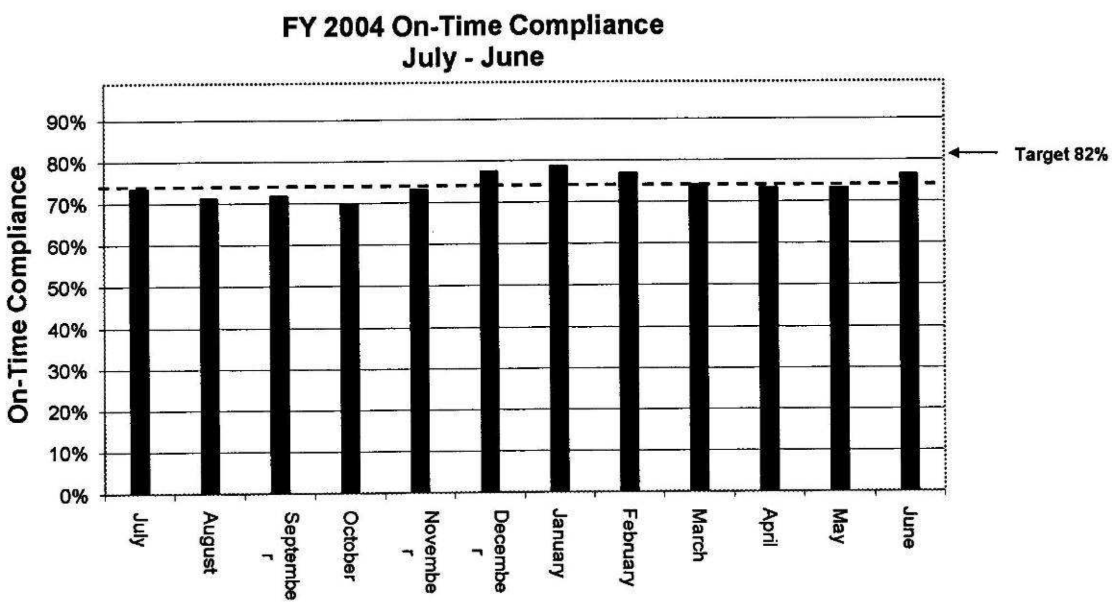

Figure 13. System Wide On-Time Performance Statistics in FY 2004[11]

[11] Buses arriving three minutes or more after the scheduled arrival time were considered late in FY 2004.

MONTH	FY07 ON-TIME PERFORMANCE	FY08 TIME POINT COUNT	FY08 DELAYED ARRIVALS 5 + MINUTES	FY08 ON-TIME PERFORMANCE
July	84.56%	96,770	16,779	82.66%
August	81.12%	100,678	18,982	81.15%
September	81.20%	86,598	15,803	81.75%
October	84.22%	94,293	14,844	84.26%
November	83.76%	89,268	14,020	84.29%
December	86.91%	87,703	12,621	85.61%
January	86.40%	91,318	9,947	89.11%
February	83.81%	89,071	12,078	86.44%
March	83.10%	97,350	13,008	86.64%
April	83.40%	96,780	13,498	86.05%
May	**82.67%**	**101,001**	**15,460**	**84.69%**
June	82.63%			
Total	N/A	1,030,830	157,040	N/A
Monthly Average	83.74%	93,712	14,276	84.79%

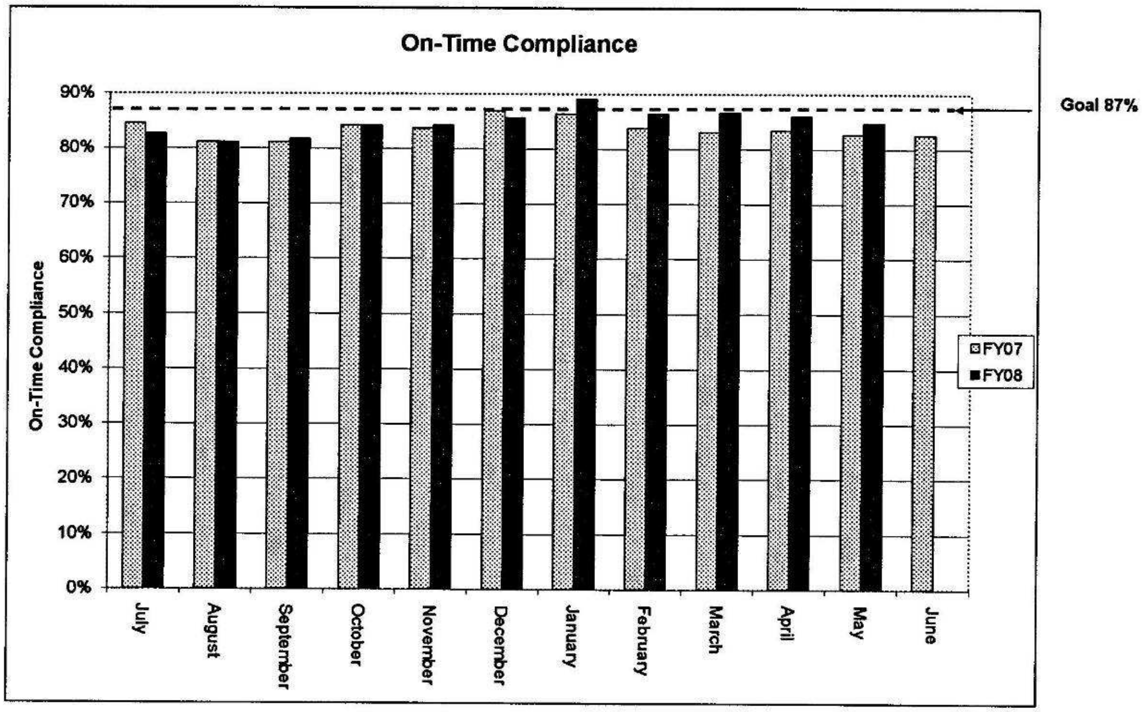

Figure 14. System Wide On-Time Performance in FY 2007[12]

As stated earlier, the ACS data has helped MST understand seasonal patterns in on-time performance (also obvious in Figure 13 and Figure 14). MST recognizes that the on-time performance is reduced during the summer season due to increases in road traffic. Also, MST believes that the rush hour traffic impacts on-time performance and consequently, adjusts schedules to provide sufficient running time for vehicles operating during peak hours

[12] Buses arriving five minutes or more after the scheduled arrival time were considered late in FY 2007.

3.1.2.3 Impact on Resource

MST did not have a significant change in staff due to the technology implementation. Occasionally, they have hired interns for preparing maps while conducting COA studies. Mostly, they use interns for GIS analysis work (using ArcView).

MST believes that technology has provided limited help in saving resources. In fact, the technology implementation has generated the need for more staff to manage and use the data generated by the deployed systems. MST spends a large amount of time in managing and analyzing the additional information generated by the ACS and other technologies. Nevertheless, it takes less time to collect data now since MST does not have to rely completely on manual data collection.

MST has recognized several benefits of technology from the scheduling system. HASTUS has allowed MST to perform runcutting in less time than it took using their prior product. Currently, it takes 2 to 3 hours to perform the runcutting. Also, MST can fine-tune blocking by bringing trips together more efficiently in the HASTUS system.

The technology has helped MST use its vehicle fleet efficiently. When MST retired 17 vehicles from its fleet they purchased only 15 vehicles to replace those 17 vehicles. Also, there has been a reduction in the number of coach operators from 132 to 123. While some of this reduction can be attributed to technology, a budget cut was partially responsible for this reduction as well.

3.1.2.4 Impact on Productivity

MST has noted that there have been improvements in productivity since the implementation of the ACS. However, MST does not consider the improvements in productivity to be an absolute indicator of good transit performance. For example, MST noticed that a reduction in productivity (e.g., passenger per revenue-hour or passenger per revenue-mile) on some routes also reduced overcrowding and resulted in faster boarding and improved on-time performance. The overcrowding on buses was reduced by restructuring of some of the MST routes to reduce transfers based on results of an analysis of the ACS data. MST analyzed origin and destination information in the ACS system for routes that were overcrowded and had poor on-time performance. MST decided to add another service to provide direct routes and reduce transfers which resulted in redistributing loads in the system.

3.1.2.5 Impact on Passenger Counting and Ridership

Before the ACS implementation, MST counted passengers using ride checkers, which required recruiting a dedicated staff. MST also used to obtain passenger counts from their fareboxes. However, the passenger counts obtained from fareboxes were not thought to be very useful since the location and time of boarding was not available from the farebox. MST believes that the time and location of boardings from the ACS assists them in reducing operational costs and revenue-hours.

MST decided to approach passenger counting in a different way than many agencies that deploy automated passenger counting (APC) systems. MST was skeptical about the reliability of APCs available in the market at the time of the ACS implementation. Instead they decided to implement an innovative solution for tracking the number of boardings with the help of the ACS system. They designed and implemented an interface on the MDT for the coach operator to enter passenger counts. MST coach operators use this interface to enter the number of boardings at each stop. This interface also allows MST to associate numeric codes with boardings to indicate the fare type. For example, MST can capture boardings during special events using a special code for such events.

The boarding counts are sent to the ACS in real-time. While MST collects its passenger counts through the use of the ACS, spot checks are sometimes conducted on overcrowded buses to ensure that the counts are being recorded accurately. At times, MST had issues with training the coach operators in using the passenger counting feature on the MST. For example, the coach operators were found entering boarding information after leaving the departure zone and had to be retrained to use the feature while the vehicle was not in motion or after leaving the stop.

Information regarding the direct impact of the ACS implementation on ridership changes was not available. However, MST adjusted certain routes based on archived ACS data, resulting in a trend of increasing ridership since 2004 (see Figure 15). The on-board rider survey conducted in December 2007 reported that 80 percent of MST riders agreed that MST service had improved since 2006. Also, MST service received an average rating of 1.7 (where, 1=excellent, 2= good, 3= fair and 4= poor) in the same survey.

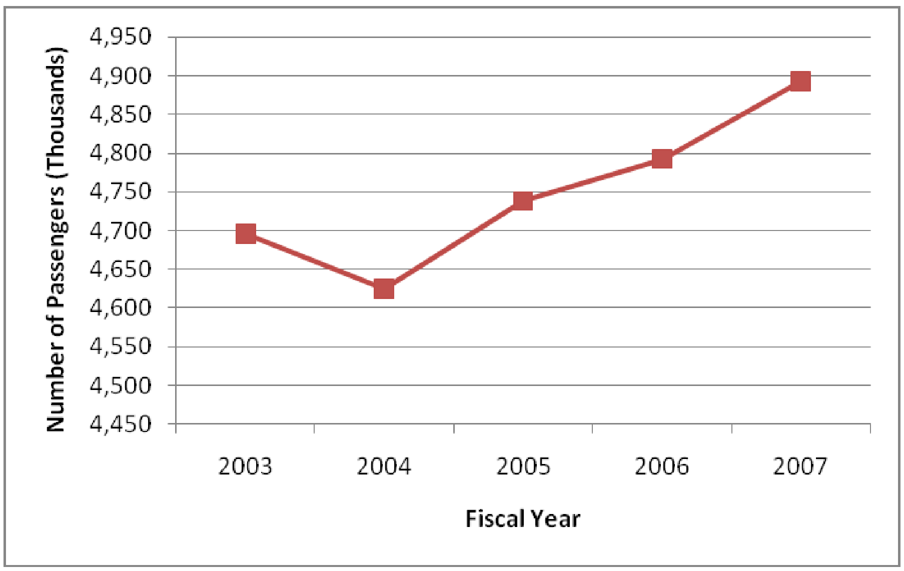

Figure 15. Annual Ridership

The passenger counting information obtained from the ACS has assisted MST in restructuring their services. For example, MST reduced service hours on certain routes that were found to have a low number of boardings during those hours.

MST experienced a ridership increase due to the deployment of on-board internet access on two long distance commuter routes: Monterey-San Jose express and Salinas-King City. MST conducted a survey in October 2007 to find out the response of riders to the Internet access. The survey results showed that riders consider this as an important amenity for commuters. The passenger survey showed that 55 percent of the respondents were aware of the on-board Internet access and 24 percent of the respondents had used the service before. Based on the initial positive response, MST is planning to install wireless Internet access at other locations such as transfer facilities and parking garages with the help of a local private partner.

3.1.2.6 Impact on Vehicle-Hours, Vehicle-Miles and Passenger-Miles

Figure 16 shows an increasing trend in the number of annual passenger-miles and serves as a positive indicator for increased ridership.

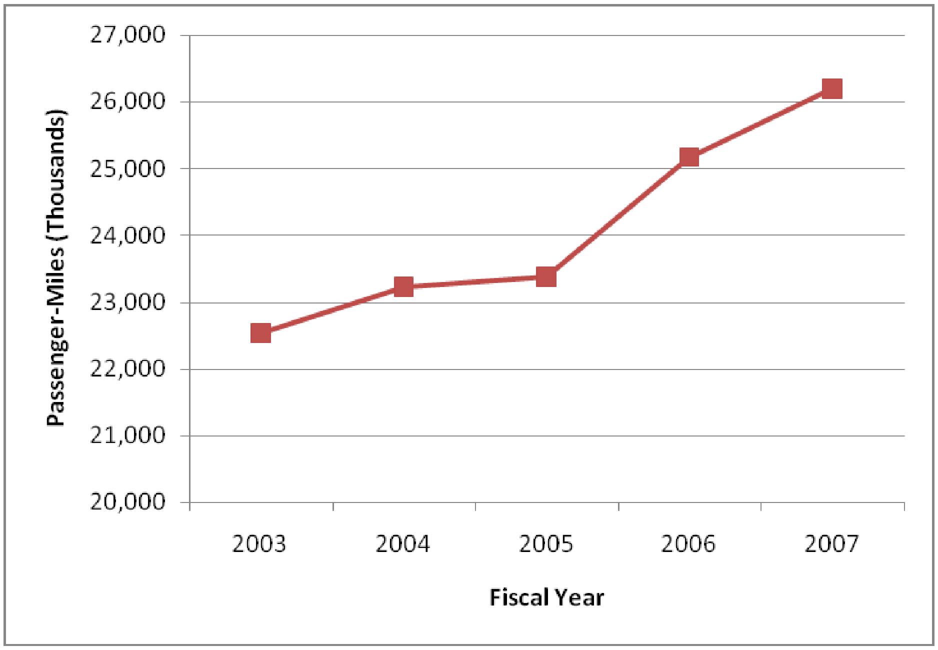

Figure 16. Annual Passenger-Miles

A review of annual vehicle revenue-miles shows an inconsistent pattern (see Figure 17). Revenue-mile statistics were the highest in 2007. However, the increase in revenue-miles cannot be attributed directly to the impacts of technology deployment, as there is limited evidence to support this claim.

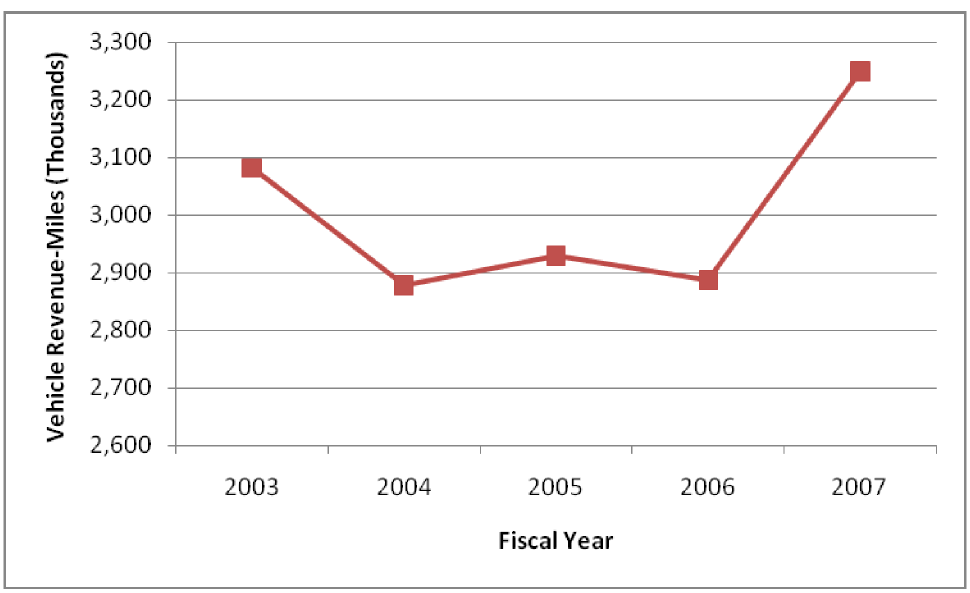

Figure 17. Annual Vehicle Revenue-Miles

Figure 18 shows an increasing trend in passenger-miles per employee since the technology deployment. This indicates that productivity has improved since the 2003. In summary, MST has served more passengers with existing resources through the use of technology.

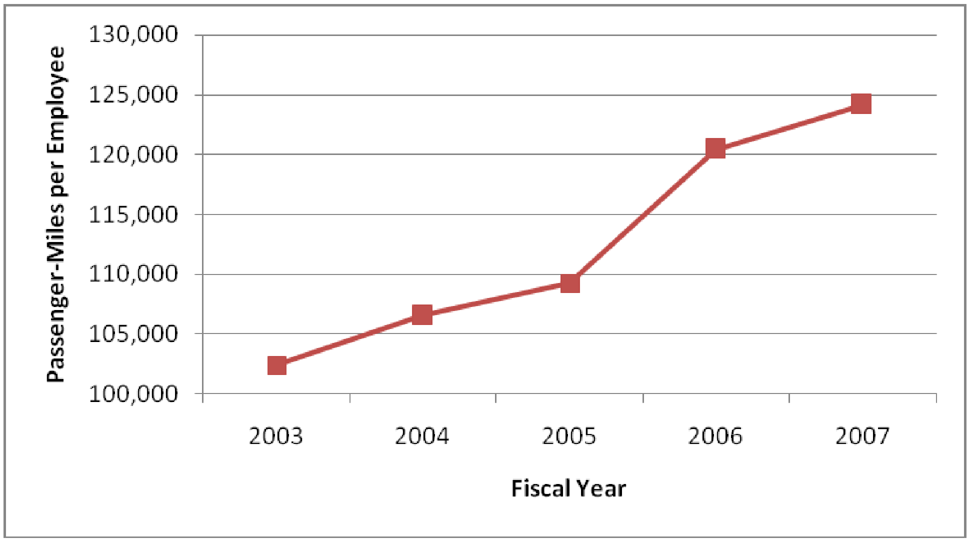

Figure 18. Annual Passenger-Miles per Employee

Figure 19 shows the trend in annual revenue-hours since 2003. This graphic shows that the annual revenue-hours did not increase or decrease consistently since the technology implementation. This trend could be a result of operational changes implemented by MST throughout the evaluation timeframe.

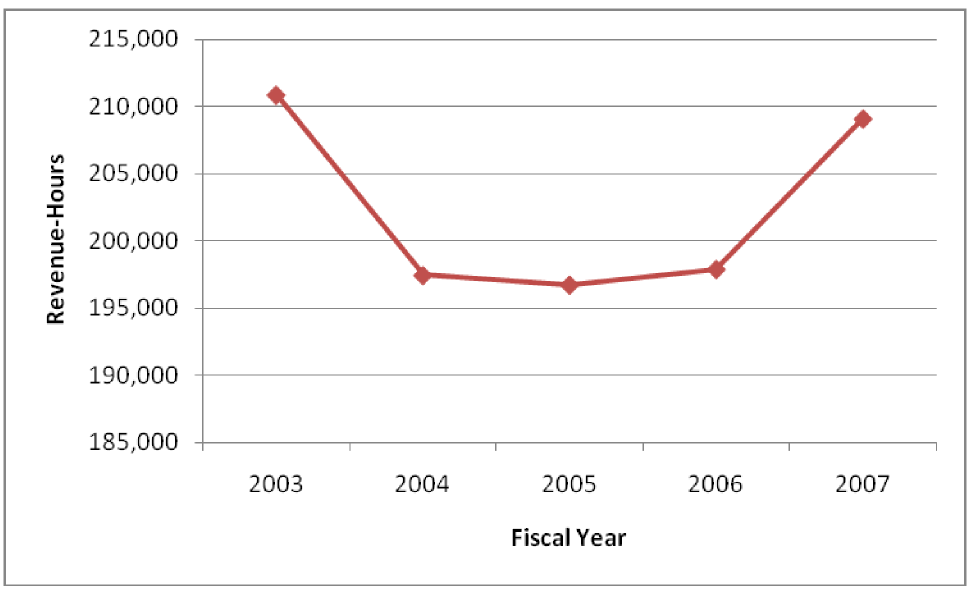

Figure 19. Annual Revenue-Hours

3.1.2.7 Other Impacts and Perceived Benefits

Generally, MST recognizes that the technology has resulted in efficiency improvements as well as increased confidence in providing accurate information to their customers. Beyond the major impacts described in earlier subsections, the ACS has assisted MST in improving activities that take place in planning and operations departments. These impacts are mentioned as follows:

- Impact of Real-time Vehicle Data: MST believes that the ACS has had more impact on various departments in comparison to other technologies implemented at MST. Primarily, the capability of the ACS to provide real-time data from the field has been of great use to all departments. MST no longer has to rely on anecdotal information from supervisors or coach operators. Further, they can integrate the anecdotal information with the field data generated by the ACS and the video surveillance system. This capability of information integration enables MST to: prioritize events or incidents, and act immediately on those events or incidents that need urgent attention.

- Impact on Planning: MST has developed innovative ways of utilizing the data from the ACS for various planning needs. For example, MST uses boarding data from the ACS to determine the stops with high boardings for installing shelters. Also, the system assists MST in determining if shelters should be moved to more appropriate locations. For example, on one of the MST routes, shelters were placed next to each other at stops even though there were not enough boardings. MST decided to move the shelters and was able to use the boarding data to convince the City Council about the decision. Also, the boarding data is used by MST to attract advertisers at shelter locations.

- Impact of HASTUS: MST implemented new contract rules in 2005 which required scheduling software that would take these rules into account. At the same time they needed to replace their existing fixed-route scheduling software so they procured new scheduling software HASTUS from Giro, Inc. HASTUS is able to handle specific contract requirements such as meal and rest breaks and can perform better runcutting than the previous software.

  Also, as mentioned earlier, MST has decided to use Google Transit trip planner, which requires a data feed to reflect service changes at the agency. HASTUS will provide the data feed for Google Transit. The data feed will be sent to Google every three months (at the time of each schedule change).

- Improvements in Service through Data Analyses: The MST planning department built an interface between Microsoft Access and the ACS database to extract specific information by writing ad-hoc queries. MST uses data from the ACS to determine the routes that do not have sufficient run-time built in their scheduled runs. Also, MST reviews and adjusts the timepoints on routes that were found to be late consistently using the results obtained from the analyses.

  Reduction in Voice Radio Traffic: Information on the average length of calls does not exist. However, MST believes that the number of voice calls has been reduced by 60 percent since the ACS implementation. One of the reasons that the number of voice calls has been reduced is that the dispatchers know the real-time locations of vehicles from ACS and need to contact coach operators only on a by-exception basis. Also, the data messaging feature in the ACS can be used when a coach operator does not need to speak to the dispatcher.

Prior to the implementation of the ACS; voice radio was the only mode of communication for coach operators, dispatchers and supervisors. At this time, the radio system was over capacity due to the high volume of voice traffic. Also, prior to the ACS implementation, every bus arriving at a transit center plaza used to call the dispatcher to hold the bus for transfer resulting in constant voice radio traffic. The number of such calls has decreased since coach operators call the dispatcher only when they need to hold the last bus for the day.

- Impact on Supervisors: The ACS system assists dispatchers in locating the nearest supervisor to a vehicle when there is an incident. Starting in September 2008, MST plans to equip supervisor vehicles with ruggedized laptops that will provide them access to the ACS while they are working in the field.

  Remote access to the ACS will be provided over a virtual private network (VPN) connection. Originally, MST requested that the ACS vendor provide a quote for remote access of ACS but they found the quote to be relatively high. Also, MST questioned the reliability of the vendor's remote access technology. Eventually, MST developed an in-house solution. The remote access capability over VPN also enables MST staff to access the ACS from home during emergency situations or non-business hours.

- Impact on Emergency Management: MST receives covert (or silent) alarms from coach operators when they indicate that there is an emergency situation. Usually, MST receives a very low number of these alarms (e.g., two alarms per month). A majority of the covert alarms received by MST are due to accidental activations. However, MST believes that this covert alarm feature has been valuable to their organization, even though they have had a very limited experience using it.

  As stated earlier, the ACS assists MST in managing the evacuation process during natural disasters such as wildfires in summer 2008. For example, during the recent Big Sur wildfires, MST was identified by the Office of Emergency Services (OES) as a secondary resource for providing evacuation services. MST developed plans to monitor the vehicles that would be part of the evacuation task-forces in the ACS.

- Impact on Coach Operators: There has been a noticeable change in the behavior of coach operator after the ACS deployment. They have become more responsive and accountable for operating their vehicles on time. This change can be attributed primarily to the real-time vehicle tracking capability of the ACS.

  Also, MST has improved their training of coach operators with the help of videos recorded by the on-board surveillance system.

3.2 Impact on Maintenance and Incident Management

3.2.1 Overview of the Maintenance Process and the Maintenance System

The maintenance department at MST maintains the fixed route vehicles fleet and relief units in-house. They follow up with contractors on the maintenance of MST RIDES vehicles and trolleys. Generally, contractors such as MV Transportation maintain their own vehicles and provide daily reports on the status of their vehicles to MST. MST is responsible for the maintenance of the major components of contracted vehicles.

The maintenance department purchased and installed a maintenance management system (MMS) from Maximus in March 2006. The MMS has been implemented at MST by integrating the capabilities of both automated fuel management (e.g., automated fuel dispensing, tracking fuel consumption and efficiency) and fleet management (e.g., work order processing and preventive management) technologies. MST procured both fleet management (i.e., FleetFocus) and fuel management (i.e., Fuel Focus) systems from Maximus.

Contractors are using the MMS at a very basic level, mostly to generate preventive maintenance (PM) reports. Even though vehicles operated by contractors are set-up in the MMS at MST, maintenance systems at these organizations are not integrated.

Initially, MST had plans to integrate the MMS with the financial and accounting management software (FAMIS). MST developed an interface with help of the FAMIS vendor but the interface was not successful. Eventually, MST decided against integrating the two systems. Since there is no interface between the FAMIS and the MMS, MST cannot automate the initiation of purchase order. However, a manual workaround for generating purchase orders for required asset components (e.g., maintenance parts) is semi-automated.

Figure 20 shows the automated fueling system installed at the MST headquarters garage. The system, known as FuelFocus, consists of several automated features such as automatic vehicle identification and odometer reading with the help of radio frequency (RF) technology and overhead sensors (see Figure 21), electronic fuel dispensing, remote access to the fuel station hardware, and data logging and report generation. This automated fuel management system assists MST in tracking and control of fuel usage by all MST vehicles.

Figure 20. Fuel Focus Hardware

Figure 21. Overhead Sensors for Automatic Identification of Vehicles

The FleetFocus component of the MMS assists MST in managing and controlling of both preventive and corrective maintenance processes. FleetFocus captures labor in real-time, and processes and monitors the status of all preventive and corrective maintenance works orders. The system can also store and report on various types of information such as equipment availability, warranty administration and inventory control.

Preventive maintenance reports are run daily from the FleetFocus module of the MMS. MST performs vehicle servicing between 1AM to 5AM at night when all buses are parked at the MST garage. All vehicles scheduled for maintenance are held at the garage and the MMS generates work orders for these vehicles. Eventually, vehicle assignments are made to mechanics at the maintenance shop.

Further, vehicle inspections are conducted every night and the inspection data is entered into FleetFocus. The maintenance department uses laptops to run local diagnosis on ITS equipment installed on vehicles. The corrective maintenance reports are generated at night and any vehicle with a defect is taken to the maintenance shop.

Each corrective maintenance workorder, identified based on vehicle inspection reports, is organized in the MMS by an individual task code. Since all maintenance tasks identified in the inspection report are coded, the maintenance reports generated by the MMS can be filtered by these task codes (e.g., which problem generated a particular work order).

The majority of the maintenance related data is collected and managed by the maintenance department electronically. Inspection data is typically entered in the MMS by a mechanic. The data-entry can take a long time for some mechanics to perform. MST believes that the data collection and reporting interface is appropriate for the end user but some of the data must be manually compiled for reporting purposes.

Figure 22 shows a vehicle undergoing maintenance in the headquarters maintenance shop.

Figure 22. An MST Vehicle in a Maintenance Shop

In addition to using the MMS, maintenance staff can access the ACS which enables them to search for various types of vehicle alarms in the ACS control log. Typical alarms captured by the ACS system are related to incidents or accidents, wheelchair issues, and mechanical failures.

3.2.2 Findings

3.2.2.1 Impact of Remote Diagnostics Data Analysis

Initially, the ACS was implemented using an alarm monitoring system (also known as remote diagnostics) for monitoring mechanical alarms. Remote diagnostics were intended to provide staff with a list of vehicle component alarms in the event queue of the ACS (e.g., engine fire, and low oil-pressure). However, the remote diagnostics system did not work as expected and was generating a large number of false alarms. Also, the Communications Center had become insensitive to the remote diagnostics since so many of them were false alarms.

MST reported that the ACS generated an overwhelming number of false alarms on a day-to-day basis. It was not practical to examine such a large amount of information in real-time, particularly since most of it was false.

The vendor was notified about the problem with remote diagnostics and provided one person on-site at MST for eight months to resolve the problem. They attempted to filter the event queue based on certain criteria but that did not resolve the problem. Eventually, MST decided to ignore the real-time monitoring of discrete alarms in 2005. Now, coach operators call the dispatcher if they notice problems with any of the on-board vehicle components. MST still refers to these alarm messages for maintenance by searching the ACS control logs but does not respond to these messages in real-time.

3.2.2.2 Impact on Maintenance Management

The maintenance department has realized the following benefits since the implementation of the ACS and the MMS systems:

- Capability to Locate Vehicles in Real-time: The maintenance department has access to the ACS and they use it to locate vehicles in real-time. This capability helps maintenance department to locate a vehicle that needs to be replaced by a relief unit or is being used for a special event.

  Occasionally, the maintenance staff uses the playback feature of the ACS to review vehicle operations.

- Change in Resources: MST had plans to reduce the number of maintenance staff, especially the parts staff, after the implementation of the MMS in 2006. This was due to the fact that the most of the maintenance information was being captured electronically. However, MST did not make any changes in the number of staff. The technologies have resulted in more responsibilities and a necessity for data management.

- Improvement in Work-Process: The MMS has improved the maintenance work process by providing better control of the maintenance workflow. The MMS allows the maintenance manager to monitor the ongoing work. Also, the performance of individual mechanics can be monitored in the MMS.

- Reporting: The reports in the current MMS have proved to be very useful to the maintenance department. For example, a certain type of report that was needed for a Board meeting could be produced with the assistance of the MMS.

- Monitoring using the Video Surveillance System: The video surveillance system was initially procured to enhance the security and safety of drivers and customers but it is also being used for various other purposes. For example, the maintenance department uses the video playback feature to monitor the quality of vehicle servicing in the maintenance shop. The maintenance department also uses facility surveillance cameras to view the buses being serviced in the shop in real-time with the help of closed circuit television (CCTV) technology.

- Secured Access to Facilities: As stated earlier, MST is planning to control access to all its facilities using a proximity card. Currently, doors at MST facilities are secured with the help of numeric codes based locks, the codes for which have to be changed very often.

  MST has already implemented a proximity card to enter the facility at the Marina Transit Exchange. The system is very useful and provides control to: identify only those employees who should have access, identify the times at which specific employees should have access, and log all facility entries and exits.

3.3 Impact on Safety and Security

3.3.1 Overview of the Security System at MST

MST procured a video surveillance system from General Electric Security (acquired from Kalatel) in FY 2002. MST buses are equipped with interior and exterior cameras. MST equipped their buses with cameras in phases, as stated previously in Section 1.2.4. Both interior and exterior cameras were installed. The exterior cameras are located (see Figure 23): in the front of the vehicle (facing outside the window), and on the left and right sides of the vehicle.

Figure 23. Exterior Camera Installations

Video is recorded on-board by digital video recorders (DVR). These DVRs can store up to 72 hours of video. The video is overwritten after 72 hours are recorded. These DVRs capture up to 500 footage-hours per day. MST downloads up to three DVRs a day for review. Central playback software is used to review the video. This capability assists MST in reviewing any accidents or incidents after the fact. These videos include both audio and video data from multiple cameras.

A panic button can be used by coach operators to tag incidents after which the DVR software increases the speed of video recording. The videos are generally recorded at three frames per second (fps). On activation of the incident tagging, recording speed increases to 30 fps. This capability assists MST to capture the full-motion view of an incident or accident.

Generally, the on-board surveillance system has provided a safer transit system. Also, the surveillance system has helped MST reduce the number of false insurance claims from customers and defend against lawsuits. Accident investigations are conducted in-house but outside consultants are involved when legal advice or assistance is required. MST has designated one staff member to perform in-house investigations. In summary, the surveillance system helps MST in:

- Resolving passenger disputes;
- Resolving complaints against drivers;

- Resolving passenger slip and falls claims;
- Verifying running red light complaints; and
- Verifying over-exaggerated complaints regarding operator assault.

CCTV video surveillance system has been installed at various physical facilities including transit centers (see Figure 24). The MST headquarters building does not yet have the surveillance system installed, but MST is pursuing a grant to install video cameras at this facility. MST believes that, as they grow, they will need to install cameras at more locations.

Figure 24. Facility Camera Installation (highlighted in circle) at Marina Transit Exchange

MST has also been planning to implement real-time video monitoring capability in which cameras will send live video feed to a central location on certain routes. However, it is uncertain whether or not MST will implement this system since its recurring cost is relatively high (e.g., $50 per vehicle per month). Also, the security staff thinks that a real-time video monitoring system is not required and the current system is sufficient to meet their needs.

3.3.2 Findings

The security department believes that implementation of the surveillance system has been very useful. Both employees and coach operators feel safer due to the presence of the video surveillance system. Also, coach operators believe that the surveillance system is for their protection and is not installed to "watch them." MST credits their union for handling the implementation appropriately.

The major impact of the surveillance system has been on the process of handling incidents and accidents, and resolution of financial claims obtained from its passengers, as described below.

3.3.2.1 Impact on the Number of Incidents/Thefts/Vandalism

When an accident or incident occurs, a road supervisor creates an incident form in the accident database of the MMS and attaches any relevant information (e.g., an image). The security department performs an investigation after receiving a claim related to an incident and attaches any further document (e.g., accident report, images, and the police report) to the initial report. The video surveillance system is not integrated with the ACS system and security investigators view the ACS control log to gather any additional information related to vehicle operations. The electronic filing of incident and accident of data has made the retrieval of information much easier for MST employees. Earlier they had to look for information records in paper files.

As stated previously, after Fall 2008, supervisors will be able to access the MMS and ACS systems from their vehicles through remote access on laptops. This capability will expedite the process of incidents and accidents investigation and will also reduce the response time of supervisors to these events.

3.3.2.2 Impact on Financial Savings

The number and amount of false insurance claims has been reduced since the video surveillance system was deployed. One of the reasons for this decrease is that passengers are aware that MST is using video surveillance and have evidence for incidents involving MST buses and physical facilities. In general, MST states that the video surveillance system has helped them save the amount equivalent to 50 percent of the cost of the camera system as of FY 2007. Also, MST stated that the camera system has reduced their liability and insurance premiums since the video surveillance system was deployed.

Figure 25 shows the amount recovered by MST per the number of claims submitted by its customers in each fiscal year. This information is not available for fiscal years prior to 2005. However, the chart shows an increasing trend since the FY 2005 and supports MST's conclusion regarding the financial savings discussed in the previous paragraph.

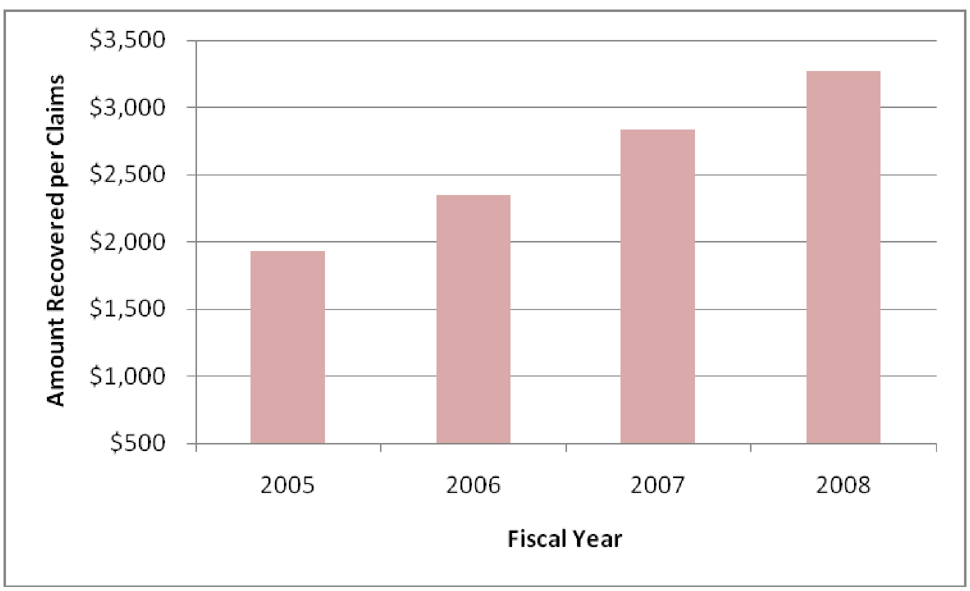

Figure 25. Amount Recovered per Claims

MST utilizes evidence from the video system to identify false passenger claims (e.g., slips and falls). MST reported that they recovered $70,000 in FY 2007 which they would have lost to customers making false claims in the absence of evidence. Before the installation of the video surveillance system, their recovery was between $800 and $1,800 per year. Also, they were responsible for $3 million in settlements without having any video evidence to backup or deny the claims.

Other impacts due to the video surveillance system are as follows:

- An insurance claim was made by a passenger against MST for $25,000 in July 2008. However, the final settlement was reduced to $2,500 when the party was made aware that MST had video evidence showing what actually happened.

- Coach operators are protected through the use of the video system when false complaints are received against them. In one instance, the video evidence helped MST to prove that their coach operator was not was not negligent as claimed by a passenger.

- As stated previously, the surveillance system has helped identify false complaints resulting in savings from the costs of lawsuits. For example, in July 2008, a particular vehicle was in the yard on a day that MST received a complaint from a passenger that that he was on this particular vehicle. The passenger claimed that he was standing because the bus was full, and ended up hitting his head when he fell down. Similarly, in a separate event, someone claimed that the bus had hit his bicycle even though the bus did not. MST was able to view the videos and prove that the complaints were false. In another incident, a coach operator saw an accident and called the Communications Center to notify them of the accident. 911 was subsequently contacted about the accident. MST received a call the next day from a person claiming that the MST bus was involved in the accident. But, the video evidence helped MST prove that that the claim was not accurate.

- One coach operator was caught stealing and his/her actions were captured on video. This operator was terminated. MST was aware that there was a discrepancy in money collection and passenger counting, and was able to investigate those discrepancies using the video monitoring system.

3.3.2.3 Other Impacts of the Surveillance System

MST has developed a good relationship with the local police department and works very closely with them by providing video information captured by the surveillance systems. MST has provided evidence in various criminal activities (e.g., bank robbery, shooting) to local police departments with the help of the surveillance system. Several examples are as follows:

- On Route 41, individuals were caught discharging a weapon, and were later identified and apprehended by the police with the help of videos provided by MST.

- MST provided video footage of a bank robbery incident in Marina.

- The local police department in Sand City asked MST for help investigating a specific criminal activity. MST was able to provide the video evidence that showed an individual being beaten. The police were able to identify and apprehend everyone who was involved in the event the next morning.

- Video evidence provided by MST helped a Salinas police officer from being suspended. The officer was accused of being involved in an accident, but MST videos proved that the police officer was not involved.

- MST provides vehicles to the local police department for exercises as part of Special Weapons and Tactics (SWAT) training. Videos recorded by MST cameras assist the police in reviewing and critiquing officers' performance in these exercises. This assistance has further strengthened MST's relationship with local police departments.

MST recognizes that passengers realize the presence of the surveillance system and consequently misbehave or vandalize much less on-board MST vehicles or while waiting at MST transit centers. Also, placards on buses notify riders that "they are being watched." This is perhaps one of the reasons why the number of rider incidents have decreased since the video system was installed.

Facility security cameras have assisted MST in catching vandals. For example, an individual was caught writing on a camera and was later identified and apprehended.

3.4 Impact on MST Reporting

MST recognizes that a large amount of data is being generated by the ITS systems installed at MST. They have limited resources with which to fully utilize all of the information. All of the deployed systems have reporting capabilities, but many of the canned reports are not very useful. For example, standard reports from the ACS currently (as of August 2008) do not meet the needs of the planning department. Planning staff have to use reports that were developed in-house using Microsoft Access. However, the ACS system provides a few monthly summary reports that are useful in presenting information to the MST Board. The finance and security departments stated that reports from the FAMIS and MMS systems do not meet their needs currently.

In order to address the agency's reporting needs, MST hired a consultant to review the information needs of each department and design reports using Microsoft Excel, Crystal Reports and other web-based tools. The new reports are expected to be designed during Fall 2008. These reports will provide information from all of the ITS systems mentioned in this report, including HASTUS, ACS, FAMIS and MMS. The following types of reports will be identified and designed:

- Board reports: to generate and provide information summaries to the Board;

- Monthly reports: to generate and provide standard monthly statistics on various performance measures (e.g., on-time performance and productivity) and ridership;

- Individual reports: to meet the information needs of individual staff from different MST departments; and

- Financial reports: to generate and provide financial (e.g., revenue and expenses) information from FAMIS, MMS and other relevant systems.

MST stated that the National Transit Database (NTD) reporting process has become easier with the presence of ridership data from the ACS. Revenue and boarding information reports are generated for

NTD after combining farebox data with ridership information from the ACS. No information was available on the relative difference in the times necessary to produce NTD reports before and after the implementation of the technologies. However, there has been some anecdotal savings. For example, while collecting data for two trips at the same time, they had to send two separate people into the field before the technology implementation. Now they can send one person into the field and assign the other person the task of counting boardings and alightings by reviewing the recorded on-board videos. Further, MST uses video recordings for verifying and correcting boarding or alighting data while doing triennial surveys.

Even though MST has various reports available to make better decisions from individual systems, they believe that a more sophisticated reporting system will be beneficial to all departments. A better reporting system will provide information across all their systems (e.g., farebox, ACS, MMS and FAMIS) through just one single interface.

3.5 Impact on Customer Service

MST has developed a customer service database in-house using Microsoft Access. This database, which provides capabilities similar to that of a customized customer service system, allows customer service staff to categorize and track all comments and complaints at any time. Generally, MST resolves most of its complaints within one month. The Customer Service (CS) department assigns each complaint to the appropriate staff based on the category of the complaint via an e-mail. CS staff can either e-mail or send a fax to the customer when the complaint is resolved. MST recognized that once they started responding to customer complaints in a timely fashion, they started receiving more complaints.

There are three ways for customers to provide their comments to MST. Comments can be submitted on the website, submitted via email, or reported via the phone or in-person. Sometimes MST receives complaints in real-time (e.g., unavailability of on-board Internet access). Overall, the CS department receives a variety of comments, feedback and complaints (e.g., vehicles not leaving on-time, late arrival of a bus and incorrect on-board next stop announcements).

The CS department has four licenses available to access the ACS. Hence, CS staff can view the real-time location of a vehicle on the ACS to answer customer queries related to the location or arrival time of a vehicle. When CS staff receives complaints related to an incident, they have the ability to playback (on the ACS) where the vehicle was and when in order to investigate the accident. Before the ACS, dispatchers were the only source of information to investigate a complaint. Also, now CS staff is stationed at CS booths at MST transit centers with direct access to the ACS, meaning that they can provide the public with real-time information

The ACS and the complaints tracking function of the CS database provide the flexibility for MST to reassign duties to the CS staff as needed. Also, CS staff is spending less time answering customer phone calls due to the introduction of other modes of communication (e.g., e-mail and sending messages through the MST website).

Since street supervisors will eventually have access to the ACS remotely on laptops, they will be more proactive in monitoring vehicle performance. MST believes that this capability will help reduce the number of complaints made about on-time performance since this will be constantly monitored in the field as well as at the Communications Center.

MST is planning to include questions regarding technologies in upcoming customer surveys. For example, in the Fall 2007 customer survey, there was a question regarding customers' experience with the new on-board Wi-Fi internet access system. Similarly, questions regarding Google Transit, real-time information signs and online pass sales will be included in future surveys.

Figure 26 shows the layout of the customer service center recently built at the Marina Transit Exchange. The center is equipped with a workstation to access the ACS and other systems as needed. Also there is a workstation for CCTV monitoring from facility cameras.

Figure 26. Customer Service Center at Marina Transit Exchange

3.6 Impact on Finance

MST deployed a financial accounting and management system (FAMIS) from Microsoft in 2006. The system, called Microsoft Dynamic NAV (formerly Microsoft Navision), enables MST to manage its financial data (e.g., general ledger, cash management, and management of accounts payable and receivables). Before the FAMIS implementation, MST was using Fleetnet for general accounting. The FAMIS provides the capability to generate reports as needed. However, the current reporting capability will be enhanced in Fall 2008, as stated in Section 3.4

MST is planning to implement a proximity card-based login for coach operators, which eventually will be integrated with the attendance management (DDAM) and payroll systems. This integration will assist MST in automating the whole payroll process since attendance information will be fed directly into the payroll system.

MST was able to raise the pay-to-platform[13] ratio to more than 90 percent since the technology (primarily HASTUS and the ACS) implementation. Before this implementation, the pay-to-platform ratio was between 80 percent and 90 percent. Also, there has been a reduction in the number of deadhead (non-revenue) miles since the technology implementation.

[13] Pay-to-platform ratio refers to the ratio of the number of pay hours to the number of platform hours. The number of pay hours refers to the total number of hours a coach operator gets paid for including regular hours and overtime. The number of platform hours refers to the time spent by a transit vehicle in service between vehicle pull-in and pull-out.

Figure 27 shows that revenue has been steadily increasing over the last five years (these figures account for the fare increases that occurred during this timeframe). The increase in revenue has been larger since 2005 as MST was able to make better use of technologies after they stabilized. Also, MST made several operational changes since 2005 (implementing the recommendations from the COA studies).

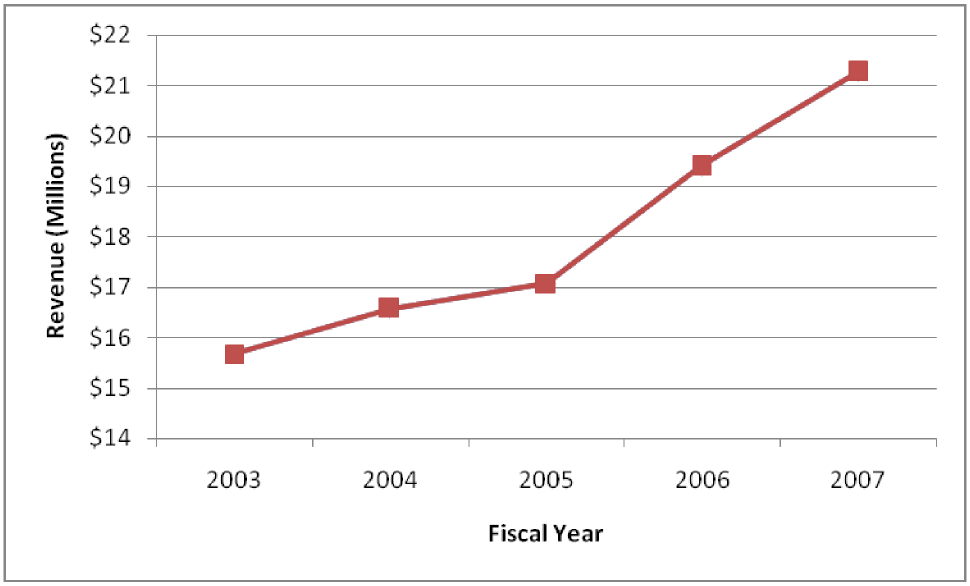

Figure 27. Annual Revenue

Figure 28 shows an increasing trend in revenue per passenger mile over the last five years. These statistics indicate MST's increase in revenue along with an increase ridership since the implementation of technologies.

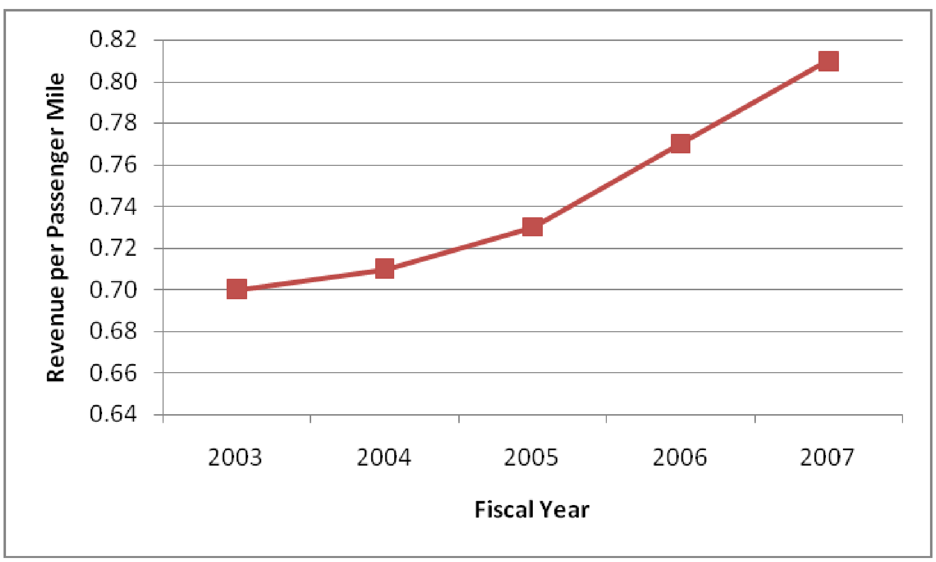

Figure 28. Annual Revenue per Passenger-Mile

3.7 *Impact on Management and Administration*

3.7.1 Improved Decision Making

The deployment of ITS technologies enables MST in making better decisions now that they have access to factual data from the field which is collected and archived by the ITS technologies such as the ACS and video surveillance system. MST staff are aware of the availability of archived ACS data and video recordings, hence, being able to verify customer complaints before reacting to a situation.

Before the technology implementation, MST's primary source of information was mostly coach operators and field supervisors. The information was anecdotal in nature, and often could not be substantiated.

3.7.2 Organizational Improvements

MST management believes that the implementation of the technologies has allowed them to function more efficiently by facilitating their daily processes. A few examples of these improvements are as follows:

- Runcutting using HASTUS helped MST management recognize that they needed a lower number of relief units. Also, they are serving a larger number of passengers within the same service hours due to more efficient scheduling and runcutting using HASTUS.

- Videos have provided information that defend route and other operational changes. Additionally, on-board and facility cameras have reduce criminal activities that involve MST vehicles or physical facilities. For example, a front-facing camera on an MST bus captured a shooting incident and assisted the local police in identifying and apprehending the criminals. As stated earlier, MST's relationship with the local police departments has improved as MST provides video and other evidence as needed.

- The COA studies conducted for Monterey Peninsula and Salinas areas used data from the ACS system. Hence, the data collection effort was significantly reduced and temporary staff was not required. Also the data was more accurate and reliable than that previously collected manually. MST management believes that they could not have done these studies in the timeframes that they did without the ACS data.

- The technology has helped to identify routes that are not cost-effective and are candidates to be operated by a contractor.

3.7.3 Increased Attention towards Future Technology Deployments

The success of technology deployment has facilitated the exploration and consideration of additional technologies for deployment. For example, after the success of the on-board Internet access program on commuter routes, MST is considering the creation of "web stations" which are stops that have wireless internet access. Further, online pass sales have increased since the introduction of on-board internet access

As mentioned earlier, MST is considering the procurement of a smartcard fare collection system, which will improve MST operations by reducing boarding times, facilitating revenue reconciliation and increasing customer convenience.

Having been impressed with the acceptance of technology by the general public, the MST Board has adopted technology as a priority for the upcoming years to make the overall system and services more attractive to existing and potential riders.

3.7.4 Change in Resources

There have been some changes in resources since the technology implementation. First, an Information Technology (IT) director position was added, and a mechanic was reassigned as an ITS technician.

There are plans to reduce the number of maintenance staff, particularly in the parts room. Due to the implementation of the MMS, most processes that were previously manual have been automated.

There have not been any reductions in operations staff, as additional staff was needed to monitor the ACS during regular service hours. Also, staff was needed to analyze the data being generated by the ACS in order to consider potential operational improvements.

3.7.5 Return on Investment

While there are no quantitative figures to provide an actual for return on investment from the technologies, MST provided the following rough estimates:

- The implementation of HASTUS has resulted in a $1 million savings annually due to its ability to incorporate contractually required items, such as meal and rest breaks, for coach operators in daily schedules.
- MST management believes that coach operator productivity has increased. Further, they feel that HASTUS runcutting has improved the pay-to-platform ratio.
- Video evidence from the surveillance system has helped MST reduce the number of false claims.
- The requirement for peak period vehicles has been reduced since the implementation of the ACS and HASTUS. As mentioned earlier, after retiring 17 buses, only 15 were needed as replacements.
- The implementation of maintenance software has improved inventory control and other functions such as warranty tracking.
- It is estimated that the implementation of the payroll system has resulted in up to $15,000 in savings per year.
- MST stopped using compressed natural gas (CNG) buses since the operating cost per hour for CNG buses was much higher than that for diesel buses. The average miles per gallon (mpg) for CNG was 1.4, while it was 5 mpg for diesel.

4 Implementation Experience

MST learned significant lessons from the implementation of the ACS, which has contributed to improving overall operations at the agency. MST had to be persistent with the vendor until the system became stable in 2005, almost four years after the start of implementation.

In general, process management during previous technology deployments was a challenge for MST. During the initial ACS implementation phase, MST had to interact with several different project managers from the vendor which made process management challenging. Also, MST recognizes that this is an ongoing challenge for MST with current implementations and will be taken into account during any future deployments.

MST's experience with the implementation of various technologies is as follows:

- The HASTUS implementation was relatively straightforward and was completed within a year. The timekeeping (DDAM) module of HASTUS was added subsequent to the initial HASTUS deployment and has been live for one year (as of August 2008).

- The FAMIS implementation started in 2006 and is not completed yet. Several modules, such as grants tracking, have not been implemented so far. MST believes that FAMIS is not functioning as expected since certain business rules are not set up correctly in the system. Also, MST cannot access some of the information stored in FAMIS (e.g., tables in the database).

- The MMS has been operating for three years (as of August 2008). MST has not faced any major issues with implementing or operating this system. They encountered relatively minor issues with the hardware that is used in the FuelFocus component at the beginning of the implementation, but that has been resolved.

- The video surveillance system implementation was relatively straightforward, and its operation has been as expected for both on-board and facility systems. As stated in Section 1.2.4, security cameras were installed on buses and inside facilities in several phases.

- MST evaluated several alternatives for an automated trip planning system before selecting Google Transit. As mentioned earlier, HASTUS provides the data feed to Google Transit through a utility that was provided by the HASTUS vendor for free. To date (as of August 2008), MST has not encountered any problems with the export from the HASTUS system to Google Transit. MST expects to go live with the Google Transit trip planner in Fall 2008.

5 Lessons Learned

5.1 Overall

MST learned several lessons regarding deployment process management, vendor management and the significance of adopting a flexible approach while overseeing numerous simultaneous project implementations over the last seven years. Some of these lessons learned are as follows.

5.1.1 Process Management

Agencies should “own” the project by having one (or more) project champion and should not solely rely on vendors to successfully conduct the implementation. Agencies should have commitment from management at the highest possible level (e.g., at General Manager level). For example, at MST, both the current General Manager/Chief Executive Officer and his predecessor were actively involved in the ITS Augmentation Project, and provided full support and commitment to the deployment of each system within the Project.

Also, agencies should appoint a Project Manager that can devote full time to the project.

5.1.2 Staffing

Agencies should be willing to increase the number of staff as needed. For example, MST needed an additional full-time staff member to monitor revenue service throughout the service day using the ACS system. Another example is that MST had to increase the number of shifts in their Communications Center in order to adequately cover monitoring the ACS system.

MST believes that it is critical to recruit “right” staff members for the project implementation and later for operations and maintenance of each system. The recruited staff should have the right talent, interest and should be receptive to new ideas. MST has increased their staff since the technology implementation, but recognizes that they probably need even more staff. For example, MST added IT Director position, an IT hardware/software management position, and an ITS technician position. But they believe that they also need a person for performing GIS analysis in the planning area.

MST recognizes that finding the right person to “get the job done” can be a challenge. On the vendor side, MST’s experiences suggest that the vendor’s project manager should understand the project thoroughly and have a competent project team to support him/her. For example, MST experienced a lot of issues with the configuration of the ACS, and it took considerable time for the project team to figure out the best solution. These issues were responsible, in part, for the late implementation of the system.

5.1.3 Flexibility

Agencies should be flexible in their expectations regarding the benefits that they can achieve from a technology. MST recognizes that sometimes it is a challenge to meet the original expectations due to several issues (e.g., technical failures, operational restrictions, and issues with institutional agreements). Further, agencies should be open to negotiate with vendors to obtain something else in exchange of the technology or component that cannot be delivered (and was identified in the original project scope). For example, MST was able to get additional licenses and spare parts in exchange for the functions that were promised by the vendor and not delivered as part of ACS.

Agencies should maintain a good personal relationship with vendors while, at the same time, being persistent about their expectations. This "good customer" attitude often leads to success for both the vendor and the agency.

5.1.4 Innovation

MST's experience is that innovative and perhaps unconventional systems can save a significant amount in cost. For example, MST decided not to implement a traditional automated passenger counting (APC) system, since they were skeptical about the reliability of APC systems in the market. Also, they thought it was not cost-effective to install a fully-functional APC system. Hence they decided to implement an interface for the coach operator to enter the number of boardings at each stop. MST developed this approach internally, and was able to use the money that they saved on another project. This innovative solution has provided MST with highly accurate passenger counts.

5.1.5 Implementation Management

MST thinks that an adequate amount of time should be allowed for implementing a technology and should not be rushed.

Further, agencies should ensure that they have right tools to operate and maintain the system. For example, MST is not able to upload the current route structure into the GIS interface of the ACS system. Hence, the mapping function displays an old route layer, with the current route traces not matching the old route traces. The ACS vendor provided a map interchange program (called "midmif") as part of the ACS, but it was never able to provide an accurate display with current route traces.

MST believes that ITS vendors should also analyze how the system would interact with other existing systems while implementing their technologies. This issue of interaction and integration with legacy systems can cause problems in the implementation process. The vendors and agency should also save mission-critical data before any software upgrade. At MST, the ACS vendor did a software upgrade in 2005, which resulted in a significant loss of data. MST was not able to restore that information.

Finally, agencies should be aware of the operations and maintenance (O&M) requirements for each system. This often gets overlooked when the focus of a project is on initial implementation. The recurring costs for operations and maintenance can be a significant financial burden on an agency.

5.1.6 Forward Thinking Approach

MST believes that agencies should be forward thinking. Once a system implementation is complete, they should start thinking about what could be done in the future. The exploration of new technologies should be critical to an agency's strategic plan as technologies change rapidly and the current systems may become obsolete in five years from the original implementation. For example, MST management will start exploring a new CAD/AVL system that is based on newer technologies. The ACS system has been deployed at MST for only six years, but it is based on much older technology.

The following sections describe lessons learned by specific departments based on their experience with deployed systems.

5.2 Planning and Operations

5.2.1 Data Utilization

MST believes that anecdotal information obtained from field supervisors and the operational data logged by the ACS system should be combined together to obtain a complete picture about an event or incident. Prior to the implementation of the ACS, the source of the majority of information was anecdotal. Now, data from the ACS system combined with information from field supervisors and coach operators can be used to make fact-based decisions.

Along with the database information, the ACS system generates control logs that provide information on the chronological sequence of operational events throughout each day. Even though the control log provides information about missed and cancelled trips, these events are not currently logged in the database under separate data columns. Currently, MST staff needs to search the control log using keyword searches (e.g., missed trip) to find the occurrence of these specific events.

5.2.2 Training

MST had some issues with the timing of the training of dispatchers on the ACS system. Training was conducted while the vendor was still trying to resolve problems with the system. Since the system was still in the state of flux, not only was the dispatchers' trust in the system lost, but also additional training was needed once the problems were resolved. MST has learned that training should be conducted once the system is fully setup and reliable.

Agency staff should be provided ample time to learn the system. They believe that vendors should have direct users of the system more involved in the implementation process. Also, they feel that agency staff should understand both the front-end (e.g., graphical user interface) and back-end (e.g., database) aspects of the system in order to have comprehensive knowledge of the system.

5.2.3 Implementation Management

Agencies should be patient during the implementation process since it often takes some time for systems to stabilize. MST had a number of "unknowns" at the beginning of the ACS installation. Most of their route surveys were incorrect and needed to be re-done. The survey errors resulted in a loss of data at the beginning of the implementation since the arrival zones were smaller than they should have been. MST adjusted timepoint boundaries (or arrival zones) before 2005 to, in part, fix the problem.

5.3 Maintenance

MST learned that they need to make much more inquiries of vendors before contracting with them. Also, after the implementation, MST learned that they have to be more pro-active and cannot just rely on vendors to maintain a stable operation. For example, one of the selling points of the ACS system for MST was the remote access capability for field supervisors. However, the vendor did not really have that module developed and operational yet. This lack of capability led MST to have to implement two shifts since there was only one workstation that could be used for monitoring by dispatchers – field supervisors did not have access.

MST has become more cautious while evaluating vendor products, but is willing to embrace a technology if it is satisfying a specific need. They think that it helped to do some research before buying specific systems, including conducting one or more site-visits to locations where the vendor's product(s) was operational.

5.4 Information Technology

5.4.1 Training

MST did not have any challenges with training per se, but found that getting people to use the system in the manner that it was intended was a big challenge. Further, as mentioned earlier, the timing of training was critical. For example, for the ACS, MST has a "train the trainer" program, but the system was not available for their use after the training. So they lost whatever they had learned during the training, since they could not use it on a regular basis.

5.4.2 Culture of Change

The "change culture" is very important for implementing technology in an organization. Many staff members are very familiar with the way an older system works, and may not be amenable to accepting new systems. For example, since MST staff is used to earlier maintenance and financial management systems, it is challenging for them to work with the user interfaces of new systems.

However, the deployment of other ITS systems such as ACS, HASTUS, and DDAM were accepted well in the organization. The primary reason for this acceptance was that their implementation resulted in a decrease in the volume of manual effort required by MST employees to perform their functions.

5.4.3 Standardization

MST believes that database and technology platforms should be standardized across agency systems. Hence, they are building other systems around the ACS. The standard platform for all technologies is Microsoft Windows and SQL Server is used for all databases except for MMS, which uses an Oracle database.

5.5 Safety and Security

5.5.1 Procurement Process

MST believes that agency staff should visit other sites that have already installed systems similar to those that they are considering for deployment. If on-site visits are not possible, agencies can participate in the American Public Transportation Association (APTA) EXPO, in which many of the technology vendors display and can demonstrate their technology. In this forum, agencies can speak with vendor representatives directly and possibly get the "feel" of the systems that they are considering.

Agencies should ensure that they specify the functional requirements and the number of units of hardware and software according to their specific needs. Also, they should be persistent with the vendor to ensure that the system they are purchasing is what was specified. This means that a rigorous implementation management approach should be used throughout the implementation (e.g., conducting design reviews, overseeing vendor installations, conducting testing according to the specifications, etc.). The vendor should not be solely relied upon to ensure a successful implementation.

If at all possible, agencies should order system components when they identify a need. Initially, MST did not deploy exterior cameras that would have provided specific views for security monitoring. They believe that the lack of these specific cameras cost them a lawsuit worth $3 million – if they had video from those specific views, the $3 million lawsuit might have been dismissed.

MST’s experience with exterior cameras suggests that they are especially beneficial in the event of accidents or incidents.

5.5.2 Technology Upgrade

MST recognizes the importance of keeping their systems up to date as much as possible. MST had to upgrade their DVRs twice when the old DVR technologies became obsolete. Also, MST’s experience suggests that agencies should ensure the consistency of various system platforms (e.g., DOS or Windows).

6 Future Evaluations

6.1 Technology Evaluations

6.1.1 Real-time Information

The real-time information portion of the Augmentation Project has been completed. MST has installed Light Emitting Diode (LED) and Liquid Crystal Display (LCD) dynamic message signs (DMS) at Marina Transit Exchange and the Salinas Transit Center.

MST is planning to install more DMS at the Monterey Bus-Stop-Shop before the end of 2008. Eventually, they would like to expand the deployment of real-time information signs to major locations such as shopping centers and major timepoints (street intersections) depending on the availability of funding in the future.

Figure 29 provides an example of the LED DMS installed at the Salinas Transit Center. One DMS has been installed in the center of each bus bay providing the scheduled departure and estimated arrival time for each bus.

Figure 29. DMS Displaying Real-Time Information at Salinas Transit Center[14]

Figure 30 shows an LCD display with a summary of the arrivals and departures at the Salinas Transit Center. The LCD DMS was installed inside the customer service kiosk at the Center to avoid any vandalism of the DMS.

[14] Photograph provided by Monterey Salinas Transit

Figure 30. DMS Displaying Real-Time Information inside Customer Service Kiosk at Salinas Transit Center[15]

MST believes that the DMS have been working as expected. They tested these DMS extensively before installing them in both locations. However, MST would like to conduct a survey at these locations to determine customers' perceptions of on-time performance and the real-time information displayed on the DMS.

The Evaluation Team will assess the impact of real-time information on MST operations during Phase III of this evaluation.

6.1.2 Transit Signal Priority (TSP)

MST vehicles have been equipped with transit signal priority (TSP) transponders[16] since 2001. Currently (August 2008), MST is exploring funding alternatives and trying to build consensus among local jurisdictions to support the implementation of TSP.

MST operates in sixteen different jurisdictions and on corridors managed by Caltrans. The traffic engineers from the local jurisdictions are not convinced of the utility of TSP. Thus, MST still needs to get buy-in from these jurisdictions to deploy TSP. Currently, MST has an agreement with only the City of Monterey, with consent from the City of Salinas still pending.

MST is trying to obtain very small start funding for the Bus Rapid Transit[17] (BRT) system. For small start funding, MST must demonstrate that the travel time can be improved by a certain percentage with the

[15] Photograph provided by Monterey Salinas Transit

[16] Transponders are installed on-board transit vehicles to emit signals to receivers installed at traffic intersections. These receivers process the signals to extend priority to transit vehicles

implementation of BRT. Hence, MST is demonstrating BRT service on Fremont Street from the City of Seaside to Monterey Bay Aquarium in the City of Monterey. MST is exploring the use of Congestion Mitigation and Air Quality (CMAQ) funding to provide a match for the small starts grant.

This impact of TSP will be evaluated in Phase III of the evaluation. Since the "before" data could not be collected in Phase II, both "before" and "after" data will be collected for this technology during Phase III.

6.1.3 Smart Card Fare Payment

MST has decided against participating in the Bay Area's Translink program due to institutional issues. They have obtained a grant from the State of California for implementing their own smartcard fare payment system. MST will explore technologies and evaluate vendor products in Fall 2008. They may host vendor demonstrations and visit other sites that already have systems installed before the procurement.

The impact of the new fare payment technology will also be evaluated in Phase III of the evaluation.

6.1.4 Google Transit

MST decided on Google Transit after evaluating several other trip planning options. MST has already provided data to perform the beta test. As of August 2008, MST is expecting to go-live with Google Transit in Fall 2008. Google Transit also provides the capability to plan regional trips in the Bay Area which will compensate for MST's decision to not join MTC's regional trip planning system.

The Evaluation Team will analyze the benefits of Google Transit during Phase III through inputs from staff interviews and customer satisfaction surveys.

6.2 Customer Satisfaction Survey

Customer satisfaction surveys will be conducted in Phase III of this evaluation. The customer satisfaction survey will be designed so that it can be completed easily by MST customers, with customers providing their answers either in a "Yes" or "No" format, or based on a simple linear scale ranging from 1 to 5, where "1" means the least effective and "5" means the most effective.

Based on discussions with the appropriate MST operations staff, the Survey Distribution Plan will identify which major stop locations and routes will be targeted for data collection activities. A local firm will be contacted to provide temporary personnel to conduct the customer satisfaction surveys. Since southern routes serve mostly Spanish-speaking neighborhoods, if these routes are selected, the Evaluation Team will develop a portion of the customer satisfaction survey in Spanish. A detailed customer satisfaction Survey Distribution Plan will be prepared during the customer satisfaction survey development stage after meeting with the appropriate MST staff and representatives from the local firm to be hired for conducting the survey.

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[17] According to the National BRT Institute (http://www.nbrti.org/, accessed on 10/21/2008), "BRT is an innovative, high capacity, lower cost public transit solution that can significantly improve urban mobility. This permanent, integrated system uses buses or specialized vehicles on roadways or dedicated lanes to quickly and efficiently transport passengers to their destinations, while offering the flexibility to meet transit demand. BRT systems can easily be customized to community needs and incorporate state-of-the-art, low-cost technologies that result in more passengers and less congestion."

At a minimum, the customer satisfaction survey may include the following questions to capture the customer's view of transit technology implementations:

- Is the customer a visitor or a regular rider?
- Does the customer use MST services daily for commuter trips?
- Does the customer think that MST has improved its on-time performance (especially since December 2002)?
- Does the customer use the MST website for schedules or rely on alternate information resources, such as talking to the helpline or printed brochures?
- Does the customer think that real-time information provided on DMS is accurate?
- Does the customer think that there is a need for publishing the real-time bus arrival status on the MST website?
- Does the customer think that planning trips with the help of an automated trip planner is better than talking to a customer service agent?
- Does the customer think that the recent changes in schedules and headways have helped his or her commute?

7 Conclusions and Recommendations

7.1 Conclusions

The evaluation of ITS deployment at MST has resulted in the identification of key factors about MST's experience related to the procurement, implementation, management and utilization of ITS technologies. Also, the evaluation identified the impacts of the technology on various departments at MST.

The following paragraphs provide a summary of the preliminary evaluation findings with respect to both key and secondary hypotheses. The results of testing the hypotheses revealed that they were either supported or inconclusive. For example, a few of these hypotheses (e.g., related to the improvement of on-time performance, and increase in ridership) were not supported by the data. The contribution of related technologies was not obvious due to involvement of external factors (e.g., service change, and operational improvements). Further, given that it takes considerable time for technologies, such as those deployed at MST, to stabilize, to become integral to agency operations and management, and to be accepted by staff, each hypothesis will be re-examined in Phase III of the evaluation to provide more definitive conclusions.

The key hypotheses for this evaluation are:

- <u>Hypothesis: The project will result in a reduction in operations and planning costs and improved service planning.</u> The Evaluation Team found increases in annual revenue and annual revenue per passenger-mile from the time of the technology implementation. However, it is not obvious that the improvements have been due to technology. Also, quantitative estimates of benefits perceived by MST departments were not available for most technologies. MST has provided some basic estimates of savings from technologies such as from the deployment of scheduling software called HASTUS, and fuel management systems as highlighted in Section 3.7.5.

  MST provided anecdotal evidence of benefits perceived from ITS implementations (as of August 2008) which provide the basis for the fact that technology contributed to service planning and operations improvements. MST reported improvements in service planning due to the accuracy and reliability of the archived ACS data used in recent comprehensive operational analysis (COA) studies. Also, MST has been able to reduce the cost of data collection by reducing the manual effort required by COA studies (e.g., recruitment of temporary staff). Among other benefits, MST utilizes archived data from the ACS for analysis with the help of other tools such as ArcView, Microsoft Excel and Access for planning needs (e.g., using passenger count data for determining stop and shelter needs and appropriate locations).

- <u>Hypothesis: The project will result in improved on-time performance of MST operation.</u> The preliminary results showed that this hypothesis cannot be supported with the currently available data (as discussed in the analysis of on-time performance in Section 3.1.2.2). The results were inconclusive because MST had several changes in planning and operations during the time period selected for analysis. Therefore, this hypothesis will be re-examined in Phase III of the evaluation.

  The intent of this hypothesis was to determine if there were improvements in schedule adherence due to the availability of real-time vehicle information for dispatchers and supervisors. Also, the Team wanted to evaluate the impact of MST's ability to adjust schedules by utilizing the archived ACS data.

However, it is not clear from the changes in on-time performance on selected routes whether those changes were due to the impact of technology or due to the operational changes.

MST staff believes (see their detailed input in Section 3.1.2.2.2) that on-time performance has improved since the technology implementation and technology has contributed directly or indirectly to this improvement (e.g., by providing data for COA analysis and subsequent service restructuring).

- Hypothesis: The project will result in an increase in the reliability of services. This hypothesis is similar to the previous hypothesis related to on-time performance and was not supported as a result of the evaluation.

  Since the quantitative assessment of ACS data is inconclusive; the reliability of MST service should be measured by performing a qualitative assessment of customers' perception of on-time performance. It is recommended that this hypothesis be revisited during Phase III of evaluation while conducting surveys to measure customer satisfaction.

- Hypothesis: The project will enhance system productivity. This hypothesis is supported by several statistics that serve as indicators of productivity improvements (e.g., revenue per passenger-miles and passenger-miles). However, these statistics are inconclusive since it is not clear from the productivity indicator data whether the improvements are due to technology implementation or other changes in the organization. MST staff believes that the technology has assisted them in increasing their productivity by carrying more passengers during the same service hours with improved scheduling. It is recommended that this hypothesis be re-examined in Phase III.

  MST also pointed out that a productivity increase may not be an absolute indicator of service improvements since a decrease in productivity sometimes benefits their organization by helping them provide on-time service. For example, reducing the number of passengers on overcrowded buses can reduce dwell times at stops, and subsequently improve the schedule adherence of those buses.

- Hypothesis: The project will result in an improvement in maintenance scheduling and planning. This hypothesis is supported by the information provided by the maintenance department during on-site interviews conducted as part of the evaluation. MST staff believes that the MMS has enabled them to track daily maintenance activities such as inventory control, maintenance-workflow management, and fuel management. Other systems such as the ACS and video surveillance system assist MST by enabling them to review on-board system performance logs and by helping them monitor the quality of maintenance work (through reviews of recorded videos), respectively.

  The Team also wanted to evaluate the capabilities and impact of the remote diagnostics system implemented as part of the ACS. However, MST discontinued the remote diagnostics feature after initial use since the diagnostics were completely unreliable. MST was receiving an overwhelming number of false alarm messages which led them to ignore the remote diagnostics.

The secondary hypotheses for this evaluation are:

- Hypothesis: The project will result in improved customer satisfaction. This hypothesis still needs to be tested. Surveys will be conducted during Phase III to determine the improvements in customer satisfaction due to the technology deployments.

- Hypothesis: The project will result in an increase in ridership. The data provided by MST shows an increasing trend in ridership since 2003. However, this information does not support the hypothesis as it is not clear if the ridership increases have been due to just technology implementations.

  This hypothesis should be revisited during Phase III by asking questions of customers regarding the impact of technologies. For example, customers should be asked whether their willingness to use and the actual use of transit has increased since the technology implementation. The customer response will assist the Evaluation Team in determining the impact of technology in customers' willingness to ride MST.

- Hypothesis: The project will result in an improvement in driver and passenger security. The Evaluation Team obtained several anecdotal references that support this hypothesis. The general perception at MST is that security systems have helped them create a safer environment for MST riders and coach operators (the term used by MST to identify bus drivers). MST has posted placards on-board vehicles that inform riders that they are under video surveillance.

  The local police consider MST buses as "mobile surveillance units." MST's ability to provide video evidence of criminal activities that involve MST buses with the help of on-board cameras has helped them improve their relationship with the local police.

  The on-board security cameras assist MST in primarily capturing evidence of any criminal activity. Additionally, these cameras have continually assisted MST in reducing the number of insurance claims submitted by passengers (e.g., related to slip and falls). Also, the video evidence assists MST in protecting their drivers from being victims of false customer complaints.

- Hypothesis: The project will result in a reduction in the travel times of specific routes where TSP is deployed. This hypothesis will be tested during Phase III of the evaluation as MST has not yet implemented the transit signal priority.

- Hypothesis: The project will help reduce response time for incidents and emergency management. The hypothesis can be supported by information provided by operations and maintenance staff. However, the Team did not receive any quantitative estimates of improvements in response time.

  The availability of the ACS assists MST staff to track vehicle locations in real-time and enables them to send a supervisor to the accident site immediately. Also, MST drivers can select a specific text message from the list of canned messages on MDTs and send that to the dispatcher to notify operations that there has been an incident, and avoid making a voice call, if possible. Text messaging capability has helped MST reduce the voice radio traffic by 60 percent. Also, starting fall 2008, MST supervisor will be able to connect remotely to the ACS to obtain any additional information that is needed while responding to an incident.

  The ACS enables MST to provide and monitor evacuation services in the event of natural disasters such as the wildfires that happened during summer 2008. For example, during the recent wildfire event in Big Sur, MST was able to develop and manage task forces using MST vehicles through the use of the ACS.

Also, the number of incidents has been reduced in recent years subsequently contributing to reduced insurance premiums.

- Hypothesis: The project will result in a reduction in vehicle hours. The intent of this hypothesis was to test that the technology has assisted MST in reducing the number of revenue hours since 2003. Since annual revenue-hour statistics do not show a consistent increasing or decreasing trend, this hypothesis could not be supported. The number of revenue-hours decreased between 2003 and 2005, but an increasing trend can be seen since 2005. This inconsistency could be due to operational changes (e.g., addition of more trips to a route) implemented by MST throughout the evaluation timeframe. This hypothesis should be revisited in Phase III of the evaluation.

- Hypothesis: The project will reduce the number of customer complaints. This hypothesis cannot be tested completely as MST does not have a record of the number of customer complaints for the "before" and "after" cases.

  MST believes that the reduction in the number of complaints should not be an absolute indicator of improved customer service. They have noticed that the number of complaints have increased since MST developed an efficient process to track and respond to a customer complaint. It is evident that customers like to provide more comments and feedback only when they are assured of receiving a response.

- Hypothesis: The project will result in improved facility security. This hypothesis is supported by the facts and anecdotal references obtained during on-site interviews at MST. The physical facilities are equipped with cameras and the closed circuit television (CCTV) technology that enable the real-time video monitoring of facilities by the safety and security group. MST staff believes that the video monitoring capability has assisted MST in reducing vandalism activities and creating a more secure environment for MST riders waiting at transit centers.

  Also, MST is planning to control access to its facilities with a proximity card. MST will be able to secure its physical facilities (headquarters and the transit centers) by restricting entrance to only authorized employees. Since, as of August 2008, this card system had not been deployed, this hypothesis will be revisited in Phase III of the evaluation.

- Hypothesis: The project will establish a comprehensive reporting system. This hypothesis cannot be supported with the available information as the reporting process could not be evaluated "before" and "after" the technology.

  However, MST staff believes that they need to improve their current reporting. The standard reports provided by various deployed systems (e.g., ACS, MMS, FAMIS) do not necessarily provide the information needed by MST employees. MST has hired an outside consultant to conduct a needs assessment for reporting. Each MST business unit (departments) is providing input so that the consultant can design reports to best suit their needs using Crystal Reports, Microsoft Excel and other web-based reporting tools. This hypothesis will be retested during Phase III.

- Hypothesis: The project will result in reduced cases of false financial claims. MST provided several anecdotal references (see Section 3.3.2.2) that serve as evidence of financial savings due to the implementation and use of technologies, primarily the video surveillance system. The video playback component of the ACS also assists MST in responding to customer complaints related to late arrivals or departures.

The on-board cameras have helped MST save money in various false complaints and accidental damage claims from passengers. MST reported that they recovered $70,000 during fiscal year 2007. However, before the installation of the video surveillance system, their recovery was only in the order of $800- $1800. Also, MST had to pay $3 million in settlements due to lack of sufficient evidence which could have been mitigated with the help of an additional exterior camera on the bus.

Even though the Evaluation Team was not able to derive conclusions on the direct impact of technology for certain expected changes (e.g., increased ridership, improved on-time performance), anecdotal information obtained from MST staff has provided significant evidence to show that, so far, technology has made significant improvements in operations and planning. Generally, technologies have played a significant role in improving the efficiency of all departments as reported by the MST management. Improved efficiency has helped MST achieve cost savings as well. It is expected that even more benefits will be realized as these technologies are relied upon even more to perform specific operational and management functions.

Technologies have primarily helped MST operations by enabling them to track their vehicles in real-time and respond to incidents and emergency situations quickly. Also, HASTUS and the ACS along with other tools have helped MST improve their planning which has subsequently helped them in running better operations (e.g., improved on-time performance resulting from route changes and schedule adjustments). The impact of the video surveillance system is significant as well because it has created a safer rider environment and has enabled MST to defend themselves against lawsuit claims and reduce insurance related costs. The maintenance department has experienced benefits through the MMS as it assists MST in improving the workflow process and quality control.

The technology implementations provided an opportunity for MST to learn several lessons that will help them in future procurements. As MST plans to replace some of their systems (e.g., the ACS) with upgraded and better technologies, they believe that the prior deployment experience gives them enough confidence to procure from and negotiate with vendors, and manage the implementation of those technologies.

7.2 Recommendations for Future Evaluations

The Evaluation Team recommends the Phase III of the evaluation be pursued to evaluate the impact of remaining technologies on MST operations. Also, Phase III evaluation can provide significant results for some hypotheses that could not be tested completely or were inconclusive in Phase II. For example, the reliability of MST can be evaluated by asking related questions during customer satisfaction interviews and analyzing survey results. On-time performance and reliability could not be evaluated in Phase II due to problems with the data used for the analysis. Also, several service and operational changes (e.g., change in routes, change in on-time performance monitoring standards) during the analysis timeframe led to inconclusive results.

The evaluation of other Phase III technologies such as real-time information and Google Transit primarily will be qualitative. The customer satisfaction survey to be conducted as part of Phase III can reveal significant findings about people's perception of these technologies. The TSP evaluation will involve both qualitative and quantitative studies including the investigation of: (1) the background traffic information before implementation; (2) improvements in travel time savings by route after implementation; (3) changes in ridership; and (4) customer perceptions of travel time improvements due to TSP.

The continuation of this evaluation is contingent on the acceptance of Phase II by USDOT. The Phase III schedule submitted earlier as part of Evaluation Plan will need to be revised to be in accordance with the Phase II completion process.

Appendix A: Hypotheses

Table 4. Key Hypotheses

Hypothesis Number	Hypothesis	MOE	Data Source	Proposed Analysis Method
1	The project will result in a reduction in operations and planning costs and improved service planning.	• Time needed to complete COA studies • Cost of COA studies • Changes to routes/services as a result of COA studies • Changes in costs to operate modified routes/services	MST staff interviews	Before and after analysis of characteristics of comprehensive operational analysis (COA) studies.
2	The project will result in improved on-time performance of MST operation	Early/late statistics	MST archived data	Before and after analysis of schedule adherence data

Hypothesis Number	Hypothesis	MOE	Data Source	Proposed Analysis Method
3	The project will result in an increase in the reliability of services	• On-time performance of whole fixed route system • On time performance by route • On-time performance by trip • On-time performance by operator • On-time performance during peak hour operation • On-time performance during off-peak hour operation	MST archived data	Analyze change in on-time performance due to the ITS Augmentation project
4	The project will enhance system productivity	• Number of passengers • Platform hours[18] • Transit vehicle miles • Boardings/hour • Passenger miles per employee or revenue dollar • Cost of operation and maintenance • Cost per passenger mile • System revenue	MST archived data	Before and after analysis of data
5	The project will result in an improvement in maintenance scheduling and planning	• Staff perceptions of the use of remote diagnostics • Number of false remote diagnostic messages • Number of total remote diagnostic messages	MST archived data regarding remote diagnostics MST staff interviews	Qualitative assessment regarding the use of remote diagnostics

[18] Platform hours refer to the time spent by a transit vehicle (in this case a bus) in service between vehicle pull-in and pull-out.

Table 5. Secondary Hypotheses

Hypothesis Number	Hypothesis	MOE	Data Need	Proposed Analysis Method
6	The project will result in improved customer satisfaction	Customer perception of the following technology elements has to be measured: • On-board automated announcements • Real-time traveler information in transit centers • Automated trip planning on website • Translink fare payment system • Changes in travel times due to changes in routes and service frequencies (headways) • Changes in wait times at stops • Change in time spent talking to customer service	Customer satisfaction survey data Surveys completed for COA studies	Qualitative analysis of customer survey data
7	The project will result in an increase in ridership	• Ridership per route • Overall system ridership • Ridership by stop • Peak ridership • Off-peak ridership	MST archived data	Before and after analysis of ridership
8	The project will result in an improvement in driver/ passenger security	• Number of on-board incidents • Number of on-board incidents where perpetrator identified • Number of transit center incidents • Number of transit center incidents where perpetrator identified	MST archived data from digital cameras MST staff interviews	Before and after analysis of the data. Qualitative analysis needed

Hypothesis Number	Hypothesis	MOE	Data Need	Proposed Analysis Method
9	The project will result in a reduction in the travel times of specific routes where TSP is deployed	• Travel time per route • Change in average vehicle speeds	MST staff Interviews MST archived data	Before and after TSP deployment analysis of travel times and vehicle speeds
10	The project will help reduce response time for incidents and emergency management	• Change in response time for incidents	Staff interviews	Before and after analysis of MST incident data
11	The project will result in a reduction in vehicle hours	• Non-revenue vehicle hours • Non-revenue vehicle miles • Revenue vehicle hours • Revenue vehicle miles	MST archived data	Before and after analysis of vehicle hours and miles
12	The project will reduce the number of customer complaints	• Change in number of complaints	MST archived data	Before and after analysis of complaint data
13	The project will result in improved facility security	• Number of registered cases of theft • Number of registered cases of theft with trespassers identified	MST archived data from digital cameras MST staff interviews	Before and after analysis of the data; Qualitative analysis needed

Hypothesis Number	Hypothesis	MOE	Data Need	Proposed Analysis Method
14	The project will establish a comprehensive reporting system.	• Change in time taken in generating daily, monthly and periodic operational reports • Change in time taken in generating annual NTD reports • Number and types of reports generated	MST staff interviews	Analysis of staff interviews; Before and after analysis of data
15	The project will result in reduced cases of false financial claims	• Financial claim statistics	MST staff interviews	Analysis of financial claims before and after the surveillance system deployment

Appendix B: Data Analysis Results

Average Lateness by Route and Day of Week

Table 6. Average Lateness for the Inbound Direction on Weekdays

Routes	2003	2004	2005	2006	2007
4	2.62	2.29	2.82	2.35	2.84
5	2.99	2.76	3.00	2.93	2.47
9	3.13	3.34	2.93	2.72	2.76
10	2.60	2.62	2.51	2.58	1.87
20	4.61	3.01	2.86	3.40	3.33
24	3.00	1.87	2.92	2.66	5.02
41	5.08	3.39	2.91	6.55	6.32

Table 7. Average Lateness for the Outbound Direction on Weekdays

Routes	2003	2004	2005	2006	2007
4	3.88	2.45	2.64	2.52	2.36
5	2.28	2.06	2.12	2.07	2.39
9	3.23	2.62	2.74	2.73	2.41
10	3.77	3.19	3.21	3.64	2.97
20	4.47	3.03	2.87	4.12	3.04
24	2.72	2.39	2.62	1.87	5.07
41	3.08	2.90	2.94	2.97	2.54

Table 8. Average Lateness for the Inbound Direction on Sundays

Routes	2003	2004	2005	2006	2007
4	1.79	1.34	1.30	2.39	3.02
5	3.45	2.17	2.50	3.50	2.21
9	2.28	2.70	1.96	2.12	2.82
10	2.61	3.01	2.71	2.25	2.25
20	4.50	2.62	2.91	2.56	2.14
24	2.78	2.72	2.68	2.56	3.26
41	7.66	4.80	4.44	5.95	6.88

Table 9. Average Lateness for the Outbound Direction on Sundays

Routes	2003	2004	2005	2006	2007
4	4.39	0.94	1.33	1.63	2.29
5	2.56	1.48	1.45	1.90	1.94
9	1.74	1.87	2.59	1.99	2.49
10	2.65	3.11	2.06	2.40	2.95
20	4.64	2.70	2.35	3.01	2.82
24	2.75	2.16	2.04	3.13	3.33
41	3.41	3.74	3.76	2.68	2.71

Average Lateness by Route and Time-of-Day

Table 10. Average Lateness for the Inbound Direction on Weekday Peak Period

Routes	2003	2004	2005	2006	2007
4	2.81	2.79	3.06	2.30	2.77
5	2.87	2.82	3.06	3.09	2.29
9	3.03	3.18	3.01	2.85	2.76
10	2.87	2.60	2.63	2.69	1.95
20	4.85	2.99	3.24	3.66	4.13
24	3.07	1.80	2.92	2.51	4.67
41	4.91	3.18	2.93	6.46	6.14

Table 11. Average Lateness for the Outbound Direction on Weekday Peak Period

Routes	2003	2004	2005	2006	2007
4	3.84	2.36	2.52	2.33	3.18
5	2.33	1.89	2.06	1.96	2.07
9	3.55	2.56	2.87	2.86	2.54
10	3.84	2.98	3.13	3.76	2.91
20	4.42	3.28	2.97	4.41	3.68
24	3.13	2.49	2.58	2.35	5.68
41	2.85	2.93	2.91	2.85	2.54

Appendix C: Questions Used in On-Site Interviews in August 2008

Questions for Each Department

1. Which technologies are currently being used by your department?
2. What overall changes have you noticed in the agency over the last five years due to the implementation of technology?
3. Please describe the biggest challenges that you have faced in implementing and using technology in your department.
4. What was the cost of the technology that you are using? Are there any recurring costs associated with the technology your department is using?
5. What benefits have you perceived from using the technology? Can you describe those benefits in quantitative or monetary terms?
6. Has there been any change in your department's staff and resources since the technology implementation? Was this change planned?
7. Please provide a brief summary of your lessons learned from the technology implementation and usage.

Questions for Management

1. Please provide the current status of the following projects:
   - Transit Signal Priority
   - Real-time information
   - Web-based trip planner
   - Integration with Translink
2. What were the most significant challenges faced during the implementation of the ITS technologies?
3. What changes have you experienced in terms of staff (e.g., turnover, necessary increases, reduction) due to the implementation of each technology?
4. Please provide information on overall lessons learned from the ITS implementation.
5. Please provide information on the overall financial savings from the ITS implementation, if any.

Questions for Planning Department

1. Have you noticed significant time and resource savings after the implementation/update of scheduling software and other planning software (e.g., HASTUS, automatic passenger counter [APC] management software)?

2. What changes have you noticed in route planning and scheduling due to the implementation of the computer aided dispatch/automatic vehicle location (CAD/AVL) and APC systems?
3. Do you use archived AVL data to make schedule adjustments (e.g., by performing running time analysis)?
4. How does APC data help in planning activities? Which reports do you use regularly? Please provide a sample of these reports.
5. Have there been any changes in ridership in recent years that can be attributed to technology implementation?
6. Please provide monthly ridership information for the time period 2003 through 2007.
7. What changes have you noticed in productivity (passengers per vehicle-hour or vehicle-mile)? Which aspects of the CAD/AVL system have helped the most in the changing the productivity in your perception?
8. Have there been travel time savings due to the implementation of the CAD/AVL system? Do you have any quantitative figures on the travel time savings since the implementation of the CAD/AVL system?
9. Have there been impacts to performing comprehensive operational analyses (COA) studies in terms of the following since 2003?

- Has the time needed to complete COA studies changed?
- Has the cost of COA studies changed?
- Have there been any changes to implementing route/service modifications (as a result of COA studies)? and
- Have there been changes to the costs to operate the modified routes/services?

10. Have there been any changes to the amount of time it takes to generate annual National Transit Database (NTD) reports due to the technology implementation?
11. What are the annual boardings per hour for each year during the period from 2003 through 2007?
12. 12. Please share your experiences with any other changes that have taken place in the process of conducting COA studies, as well as performing other planning activities.

Questions for Operations Department

1. Please provide current information for the following items:
    - Number of drivers
    - Number of road supervisors
    - Number of dispatchers
    - Number of revenue and non-revenue vehicles
2. Have there been any changes in recent years to these numbers which can be attributed to technology implementation?
3. Which functions of the CAD/AVL system have helped you the most in managing daily operations?
4. Do road supervisors have access to the CAD/AVL system when in the field?

5. What changes have you noticed in the efficiency of communication between dispatch and road supervisors since the CAD/AVL implementation?
6. Have there been significant changes in the volume of voice radio traffic over the last five years? Do you think that the CAD/AVL system has contributed to reducing the number and length of calls among dispatchers, drivers and road supervisors?
7. Have there been any changes in dispatcher's response time to incidents and accidents? Has emergency communication improved with the use of silent alarm monitoring (if that is part of the CAD/AVL system)?
8. What changes have you seen in recording/reporting incidents and accidents over the last five years? Are the changes attributable to the CAD/AVL system or other technology?
9. Has the on-board surveillance system helped in improving operations? What are the significant impacts of this technology (e.g., resolving accident/ passenger disputes regarding on-time arrival of a vehicle)? Please provide anecdotal information, if possible.
10. Please provide the following annual statistics for each year of the period 2003 through 2007:
    - Total non-revenue vehicle hours;
    - Total non-revenue vehicle miles;
    - Total revenue vehicle hours; and
    - Total revenue vehicle miles.
11. Do you think that the technology has helped improve the reliability of MST transit services? Is there any documentation available on service reliability both before and after the implementation of the CAD/AVL system?
12. Does on-time performance vary significantly 1) seasonally; 2) over a week; or 3) during the day?
13. Please describe how the following functions have changed over the last five years since the implementation of technology:
    - On-time performance management;
    - Daily recording and reporting procedures;
    - Answering customer queries in the field;
    - Performing required next-stop announcements; and
    - Performing passenger counts (ride checks).

Questions for Maintenance Department

1. Is the inventory management system linked to the financial management system? How much has the new CAD/AVL system changed your job functions?
2. Please describe a typical vehicle maintenance procedure in terms of the process you use to initiate a maintenance action and to record all of the activities performed as part of that maintenance activity. Does technology play a role at any point during a maintenance action?

3. Does technology help you manage your time and resources? What technology has helped you the most in managing your time and resources?
4. What is your experience with the remote diagnostics system in terms of the following:
5. Your general perceptions associated with using remote diagnostics and the accuracy of the remote diagnostics system;
6. The total number of alarms/messages that are generated by the system during the course of an average day;
7. The alarms that you monitor;
8. The number of false remote diagnostic messages that are generated during the course of an average day;
9. The process associated with handling false messages/alarms; and
10. Cost savings since the remote diagnostics system was implemented, if any.
11. Please provide us anecdotal information on how the remote diagnostics system has helped vehicle maintenance activities since the system was implemented. What are the most significant issues with the remote diagnostics system, and how would you suggest the system be improved?

Questions for Safety and Security Department

1. Please provide the annual number and types of incidents (on-board and transit center) before and after the implementation of the surveillance system.
2. Please provide anecdotal information on investigations of reported incidents using archived videos since the implementation of the surveillance system.
3. If possible, please provide the following information annually for the period 2003-2007:
    - Annual number of on-board incidents
    - Annual number of on-board incidents where the perpetrator was identified
    - Annual number of transit center incidents
    - Annual number of transit center incidents where the perpetrator was identified
    - Annual number of registered cases of theft
    - Annual number of registered cases of theft where the trespasser was identified
    - Annual trend of customer complaints related to safety and security

Questions for Customer Service Department

1. What changes have been made to customer service hours/shifts, if any over the last five years?
2. How long, on average, does it take currently to find an answer to a customer query compared to the time it took before the implementation of technology? Has the process used to answer customer questions changed due to the use of technology?
3. Please describe the following with respect to technology implementation:

- The change in the number of customer calls;
- Changes in nature of calls; and
- The change in the number of complaints.

4. Have you received any customer feedback on technology (e.g., automated next-stop announcements, on-board and transit center surveillance)?
5. Have you conducted any surveys since the technology implementation to determine customer satisfaction with the “customer-facing” technologies? If yes, please provide the survey findings.

Questions for Finance Department

1. Please provide the annual statistics for the following for each year from 2003 through 2007:
   - Number of passengers;
   - Total platform hours (time spent by vehicle in service between pull-in and pull-out);
   - Total vehicle miles;
   - Total annual revenue;
   - Passenger-miles per employee;
   - Passenger-miles per revenue dollar;
   - Total cost of operations and maintenance; and
   - Cost per passenger-mile;
2. Please provide information on the changes in the volume and dollar amount of financial claims over the last five years due the availability of data from ITS technologies (e.g., video clips and images, and on-time performance data).

Questions for Information Technology Department

1. Please describe how various ITS systems are integrated (e.g., CAD/AVL and scheduling). If possible, please provide a system diagram that shows how systems are integrated. If possible, please identify (on a system diagram) the data flows among the various ITS systems.
2. What changes have taken place in terms of daily reporting (e.g., number and nature of reports) before and after the technology implementation? Please describe the benefits of reporting in terms of the following:
   - The number of reports by category;
   - Ad-hoc reporting capability;
   - System capability to report in various formats (e.g., graphically, map-based and tabular);
   - The resources needed to generate reports; and
   - The operational benefits perceived by other MST departments.
3. Do you manage ITS hardware, software and data in-house? If any items are outsourced, which functions were outsourced and why?

4. Which technology has helped the most in improving overall operational efficiency and productivity?
5. How long did it take to “stabilize” each of the ITS subsystems? Please provide anecdotal information on the challenges and problems that were encountered with each system/subsystem during and after the implementation.
6. Have you faced any challenges in training the staff on technology usage?